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Delaware 2011 Remote Sensing Survey

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Department of Natural Resources and Environmental Control

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Glossary of Terms and Abbreviations

ADT	Average Daily Traffic
ASM	Acceleration Simulation Mode
Basic I/M	A set of vehicle I/M program inspection requirements defined by the U.S. EPA that may be used in areas not required to implement an Enhanced I/M program; the inspection procedure usually involves idle testing
Clean Screening	The process of identifying vehicles with low emissions that are then exempt from emission inspection at an inspection station
CO	Carbon monoxide
CO ₂	Carbon dioxide
Cutpoint	An emissions level used to classify vehicles as having met an emissions inspection requirement
DNREC	Department of Natural Resources and Environmental Control of the State of Delaware
Enhanced I/M	A set of more rigorous vehicle I/M program inspection requirements defined by the U.S. EPA that usually involves IM240 testing
EPA	United States Environmental Protection Agency
Excess Emissions	Vehicle emissions that exceed an I/M cutpoint
FTP	Federal Test Procedure
g/mi	Grams per mile, the units of measurement for FTP and IM240 tests
GIT	Georgia Institute of Technology
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
High Emitter Identification	The on-road identification of vehicles with high emission levels
I/M	Inspection and maintenance program
Idle Test	A tailpipe emission test conducted when the vehicle is idling and the transmission is not engaged
IM240 Test	A loaded-mode transient tailpipe emission test conducted when the vehicle is driven for up to 240 seconds on a dynamometer, following a specific speed trace that simulates real world driving conditions

KW/t	Kilowatts per metric ton, the units of measurement for vehicle specific power
LDGV	Light-duty Gasoline-powered Vehicle
LDGT	Light-duty Gasoline-powered Truck
NO _x	Oxides of nitrogen, usually measured as nitric oxide (NO)
OBDII	On board diagnostic system to detect emissions related problems that is required on all 1996 and newer light-duty vehicles
Repairable Emissions	The emission reductions that can be obtained by repairing a vehicle. The amount of repairable emissions is equal to or greater than the amount of excess emissions
RSD	Remote Sensing Device
VIN	Vehicle Identification Number
VDR	Vehicle On-road Record
VMT	Vehicle Miles Traveled
VSP	Vehicle Specific Power; estimated engine power divided by the mass of the vehicle
VTR	Vehicle Test Record

1. INTRODUCTION

The 1990 Federal Clean Air Act Amendments require that I/M Programs be implemented in urbanized areas in certain areas to help achieve or maintain attainment of national air quality standards.

Delaware currently operates a test-only, centralized Low enhanced Inspection and Maintenance Program (LEIM) in New Castle and Kent Counties and an I/M program in Sussex County. Motor vehicle emissions tests are performed on all light-duty vehicles weighing up to 8,500 pounds gross vehicle weight at the Delaware Division of Motor Vehicles. Biennial inspections are required for model years 1968 and newer light duty passenger vehicles and model years 1970 and newer light duty trucks with the exception of the five most recent model years. OBD inspections are performed on all 1996 and newer light-duty vehicles and light-duty trucks equipped with certified on-board diagnostic systems (OBD). The exhaust of non OBD equipped vehicles is inspected with Idle or Two Speed Idle tests that measure HC and CO. Evaporative tests are also performed.

The Clean Air Act Amendments of 1990 require Enhanced I/M program areas to supplement emissions testing at stations with on-road testing. The Department of Natural Resources and Environmental Control (DNREC) contracted Environmental Systems Products (Envirotest) to conduct a remote sensing device (RSD 0.5%) survey to meet this requirement.

Fleet Emissions

Emissions of 13,266 vehicles were measured on-road in Delaware with visible plates and of these, 11,089 (84%) were identified as Delaware registrations. Average emissions of Delaware registered vehicles were 19 ppm HC hexane, 0.13% CO and 183 ppm NO. Emissions of vehicles with out-of-state plates were 15% and 12% lower for HC and CO than Delaware plates. NO emissions of vehicles with out-of-state plates were 13% higher.

Average HC and NO_x emissions by model year for Delaware registered trucks and light passenger vehicles are shown in Figures 1-1 and 1-2. The trucks measured with visible plates were virtually all 10,000 lbs GVWR or lessⁱ

The charts show that newer model year vehicles have substantially lower emissions than older vehicles. HC & CO emissions were highest among 1985 and older models. NO emissions were highest in 1991 and 1992 models.

Average emissions were influenced upward by old vehicles and a small percentage of high emitters. Median emissions were lower at 2 ppm HC, 0.02% CO and 17 ppm NO.

High Emitters

Two hundred sixty-seven vehicles with on-road emissions exceeding 500 ppm HC hexane or 3% CO or 2000 ppm NO were identified as high emitters. These were 2.6% of

ⁱ . Heavy-duty trucks with vertical exhaust stacks are not measured by RSD without a special set-up.

the vehicles measured but emitted up to 49%, 27% and 24% of HC, CO and NO respectively. Details of these high emitters are provided in section VI.

FIGURE 1-1 AVERAGE ON-ROAD HC EMISSIONS

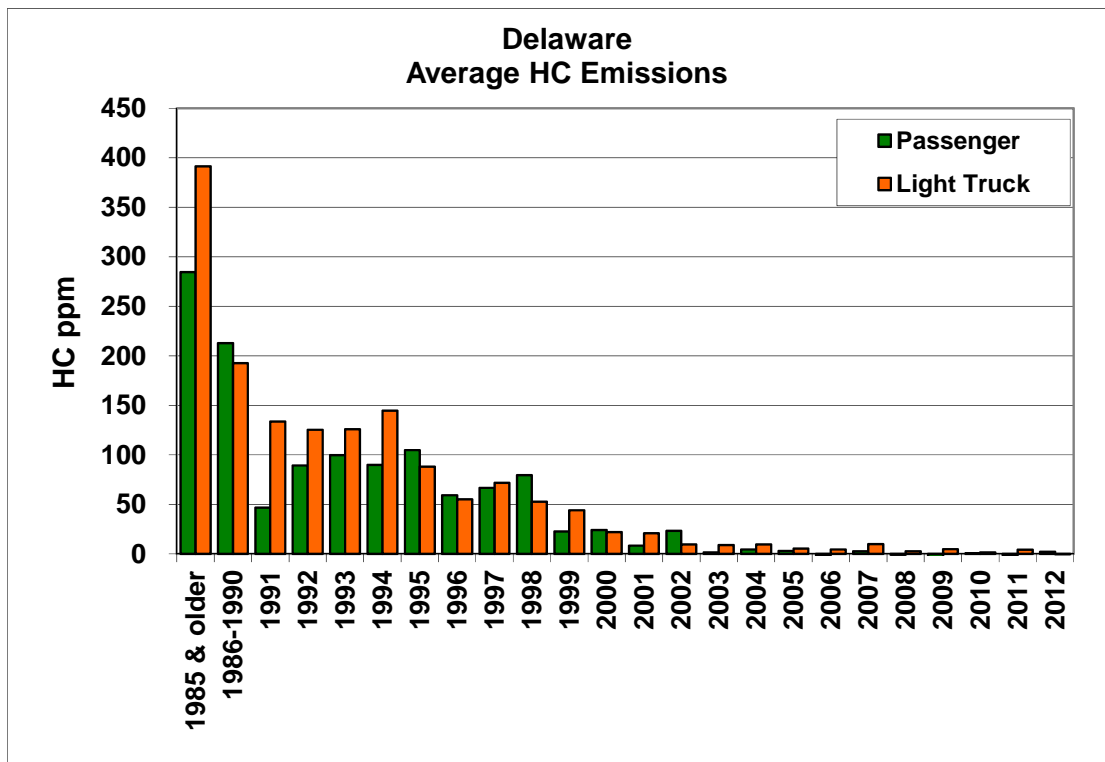
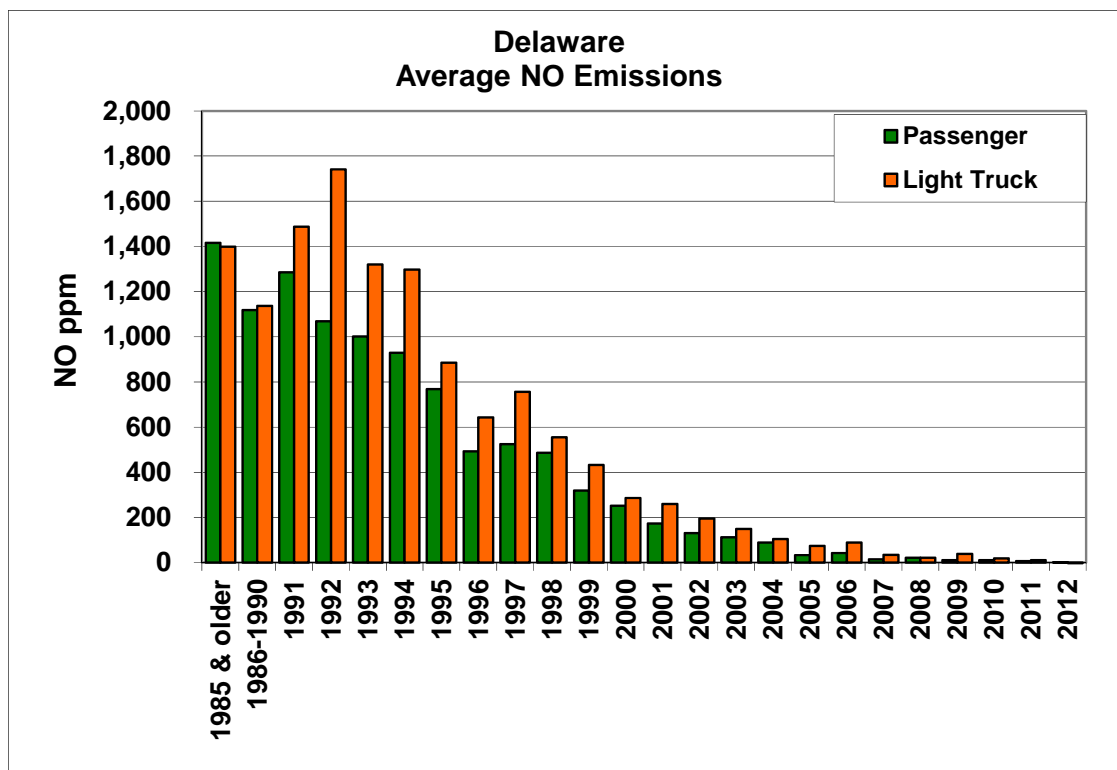


FIGURE 1-2 AVERAGE ON-ROAD NO EMISSIONS



2. STUDY DESIGN

Section 51.371 of the Code of Federal Regulation (CFR) covering Enhanced I/M programs defines on-road testing as the measurement of HC, CO, NO_x and/or CO₂ emissions on any road or roadside in the non-attainment area or the I/M program area. On road testing is required in enhanced I/M areas and is an option for basic I/M areas.

The general requirements specified in CFR 51.371 are:

- On-road testing is to be part of the emission testing system, but is to be a complement to testing otherwise required.
- On-road testing is not required in every season or on every vehicle but shall evaluate the emission performance of 0.5% of the subject fleet, including any vehicles that may be subject to the follow-up inspection provisions of paragraph 4 (below), each inspection cycle.
- The on-road testing program shall provide information about the emission performance of in-use vehicles by measuring on-road emissions through the use of remote sensing devices or roadside pullovers including tailpipe emission testing. The program shall collect, analyze and report on-road emissions data.
- Owners of vehicles that have previously been through the normal periodic inspection and passed final retest and found to be high emitters shall be notified that the vehicles are required to pass and out-of-cycle follow-up inspection; notification may be by mailing in the case of remote sensing on-road testing or through immediate notification if roadside pullovers are used.

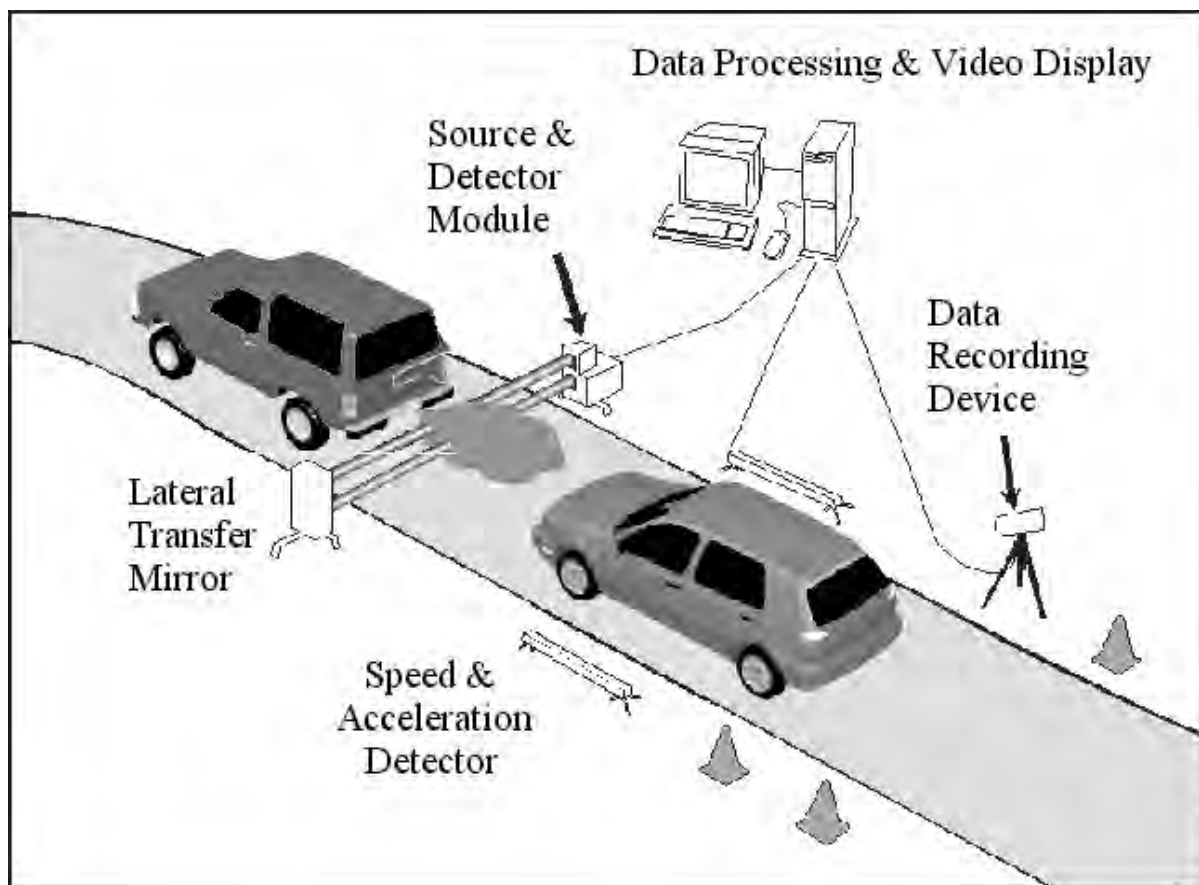
Following sections describe how these requirements have been fulfilled.

2.1 EQUIPMENT DESCRIPTION

The Delaware survey was performed using a remote sensing RSD4600 system. The RSD4600 detects vehicle emissions when a car drives through an invisible light beam the system projects across a roadway.

Figure 2-1 illustrates the remote sensing equipment set-up. The process of measuring emissions remotely begins when the RSD4600 Source & Detector Module (SDM) sends an infrared (IR) and ultraviolet (UV) light beam across a single lane of road to a lateral transfer mirror. The mirror reflects the beam back across the street (creating a dual beam path) into a series of detectors in the SDM.

FIGURE 2-1 ON-ROAD REMOTE SENSING SET-UP



Fuel specific concentrations of HC, CO, CO₂, NO_x and smoke are measured in vehicle exhaust plumes based on their absorption of IR/UV light in the dual beam path. During this process, the data-recording device captures an image of the rear of the vehicle, while the Speed & Acceleration Detector measures the speed of each vehicle.

The RSD units are housed in fully outfitted vans equipped with heating/cooling, a generator, and adequate storage for all components. The vans carry a full complement of road safety equipment and tools for making small repairs. The vans are equipped with additional lighting for testing during pre-dawn and post dusk hours. The new RSD4600 includes the following features:

- Simple and easy setup with laser alignment aids
- Alignment platforms to facilitate a fast and secure alignment result
- Continuous automatic CO₂ for background compensation that minimizes the need for field calibration. (Only one or two calibrations are generally required during a full day of data collection.)
- Fourth generation real-time measurement validation
- Signal sensitivity and accuracy that significantly exceed 2002 California BAR certification standards
- A multi-tasking Windows operating system

- A fuel specific smoke measurement using a UV wavelength that senses the fine particles invisible to traditional visible light opacity meters
- Rugged assemblies that result in high availability.

2.2 EQUIPMENT QA/QC AUDITS:

2.2.1 FACTORY TESTING AND CERTIFICATION

When an RSD system is built at the Tucson Technology Center, it undergoes several steps to ensure accuracy. First, the source detector module is bench calibrated. It is then audited using several blends of gas. When the system is fully calibrated and assembled, it is tested again in the parking lot using an audit truck. The unit tests are based on the BAR OREMS specification.

An audit truck is a modified vehicle that uses a long exhaust stack to direct the vehicle engine exhaust upwards and away from the roadway. Audit gases of known concentrations are dispensed through a simulated tailpipe routed to the rear of the audit truck. When the truck is driven past a roadside remote sensing SDM/VTM set of modules, the system measures the pollutant concentrations in the dispensed test gas instead of the vehicle engine exhaust.

The remote sensing unit is setup in a parking lot to avoid interference from other traffic. The auditor drives the audit truck through the remote sensing system 40 times for each gas blend during acceptance testing. Envirotec detector accuracy, including speed and acceleration, will meet the detector accuracy tolerances shown below for at least 97.5% (39/40) runs for each gas. Six different audit gas blends are used to verify the unit accuracy over a range of pollutant concentrations.

2.2.1.1 DETECTOR ACCURACY:

The carbon monoxide (CO %) reading will be within $\pm 10\%$ of the Certified Gas Sample, or an absolute value of $\pm 0.25\%$ CO (whichever is greater), for a gas range less than or equal to 3.00% CO. Negative values shall be included and will not be rounded to zero. The CO% reading will be within $\pm 15\%$ of the Certified Gas Sample for a gas range greater than 3.00% CO. Negative values will be included and will not be rounded to zero.

The hydrocarbon reading (recorded in ppm propane) will be within $\pm 15\%$ of the Certified Gas Sample, or an absolute value of ± 250 ppm HC, (whichever is greater). Negative values will be included and will not be rounded to zero.

The nitric oxide reading (ppm) will be within $\pm 15\%$ of the Certified Gas Sample, or an absolute value of ± 250 ppm NO, (whichever is greater). Negative values shall be included and will not be rounded to zero.

2.2.1.2 SPEED AND ACCELERATION ACCURACY:

The vehicle speed measurement will be accurately recorded within ± 1.0 mile per hour.

The vehicle acceleration measurement will be accurately recorded within ± 0.5 mile per hour / second.

2.2.2 DAILY SET-UP AND CALIBRATION

Units are equipped with an internal calibration gas cell, which has a specific set of concentrations. As part of standard procedure, the operator must first set up the retro reflector on the far side of the road and conduct a mirror alignment check. The RSD unit sends infrared and ultraviolet beams across the roadway. These beams are reflected by the mirror and detected by the RSD unit. The RSD detectors create a voltage in response to particular infrared and ultraviolet frequencies. The presence of proper voltages across all detectors verifies that the RSD unit and the mirror are properly aligned. Second, the unit is calibrated to the calibration cell values.

The next step is to verify the unit calibration. This is referred to as a puff audit. Calibration gas is introduced into the IR/UV path. This is accomplished through a calibration gas cylinder, a stainless steel gas regulator, fittings and tubing to deliver the calibration gas to the source detector module (SDM). The operator will then introduce the calibration gas into the IR/UV path via a spray nozzle at the end of the tube. The instrument displays the readings on the screen. The RSD unit response is automatically compared to the calibration gas and required to be within specification limits.

Calibration for the RSD4600 occurs once at the beginning day and at mid-day if conditions warrant.

2.2.3 EQUIPMENT AUDITS

After each daily calibration, the Operator is required to perform an audit to verify an optimal calibration. This is done in the same manner as the calibration except the audits are “earmarked” in the data file with an “A”. If the audit passes a predetermined pass/fail tolerance, the operator is allowed to begin testing vehicles. If not, the operator is required to realign and recalibrate the system until it passes the audit process. The Operator thereafter is prompted by the system to perform an audit every two (2) hours to verify the calibration.

2.2.4 QUARTERLY AUDITS (DRIVE-BY AUDITS)

An Audit Truck is used to conduct an on-road audit of the RSD4600 system approximately every three months. The audit truck is outfitted with a gas cylinder rack that holds a maximum of 6 compressed gas cylinders. Each gas cylinder is equipped with a high flow regulator, a high flow solenoid and a Tygon hose, which is adapted to a simulated tailpipe. Inside the truck cab, the audit truck operator has the ability to switch power from solenoid to solenoid to select the appropriate audit gas cylinder for drive-by audits. A traffic cone is placed 60-70 feet preceding the test site. This is used

as a mark to begin the flow of gas to ensure there is an adequate plume of audit gas as the truck passes the RSD4600. The typical gas blends used in the audits are show below:

	HC (ppm)	CO	CO2	NO _x (ppm)
Blend # 1	500	0.5%	14.70%	3000
Blend # 2	3000	1.00%	14.38%	2000
Blend #3	2000	2.75%	13.10%	500
Blend #4	6000	5.00%	11.55%	250

In addition to the equipment, the operator is also audited for following procedures: site setup, calibration, camera alignment, traffic safety and documentation.

2.2.5 NO VS. NOX

The vast majority of nitric oxides emitted from the vehicle tailpipe are in the form of NO. The NO is later oxidized to NO₂ and other oxides of nitrogen, which are collectively referred to as NO_x. The RSD unit measures NO. To convert from NO to NO_x, a factor of 1.03 can be applied. For simplicity we refer to NO measurements when reporting results. Charts in sections III and IV report NO values.

2.2.6 NOX AND HUMIDITY

Higher humidity reduces vehicle NO and NO_x emissions. For loaded mode dynamometer tests, humidity correction factors are usually applied to adjust the NO_x measurements to values that would have been achieved when the water vapor content is 75 grains per lb.

Sections III and IV report actual on-road NO emissions. They have not been adjusted for humidity. Correction factors can be calculated using the weather information recorded by the weather station attached to the RSD van.

For temperatures above 75 F:

$$\text{Correction factor} = e^{(.004977*(H-75) - .004447*(T-75))}$$

For temperatures below 75F:

$$\text{Correction factor} = 1/(1.0 - .0047*(H - 75.0))$$

Where:

H = absolute humidity in grains of water/lb dry air

T = Temperature (F)

Both of these are capped at 2.19.

Water vapor grains per lb are determined using the temperature, relative humidity and barometric pressure:

$$\text{Saturated Vapor Pressure} = (-4.14438 \times 10^{-3} + 5.76645 \times 10^{-3} \times [\text{Temp F}] - 6.32788 \times 10^{-5} \times [\text{Temp F}]^2 + 2.12294 \times 10^{-6} \times [\text{Temp F}]^3 - 7.85415 \times 10^{-9} \times [\text{Temp F}]^4 + 6.55263 \times 10^{-11} \times [\text{Temp F}]^5) \times 25.4$$

$$\text{Grains per lb} = (43.478 \times [\text{Relative Humidity}] \times [\text{Saturated Vapor Pressure}]) / ((([\text{Barometric pressure Hg mm}] - ([\text{Saturated Vapor Pressure}] \times [\text{Relative Humidity}] / 100)))$$

2.3 SITE LOCATIONS

Envirotest selected five sites in Delaware. The sites were selected to:

- Provide a representative sampling of the I/M area fleet.
- Obtain measurements in each county.

Table 2-1 lists the set of site locations visited during the study and the days the site was used. Table 2-2 list the number of passing vehicles measured, valid measurements, active collection hours, valid measurements per hour and the percentage of attempted measurements that were successful. Vehicles that are decelerating often have insufficient exhaust volume for a valid emissions measurement. Between 4,400 and 6,400 valid measurements were obtained in each county.

Figure 2-2 displays the locations of the sites.

Table 2-1: Site Locations

Site	Description	City	County	Slope
DE01	SR 2 (Kirkwood Hyw) to SR 141 N/S	Wilmington	New Castle	0.7
DE03	SR 4 (Market St) EB to SR141 SB	Wilmington	New Castle	2.4
DE05	US 13 (S Dupont Blvd) to SR 1 Korean War Memorial N/S	Smyrna	Kent	0.2
DE09	US 9 (W Market St) East, after US 113 (Dupont Blvd)	Georgetown	Sussex	0.4
DE10	US 9 (Savana Rd) West, just pass Wescoats Rd	Lewes	Sussex	0.5
DE11	US 40 / US 13 North to I-295 North	New Castle	New Castle	0.6
DE12	US 13 North to DE 1 North	Dover	Kent	0.5
DE13	DE 20 West, just past US 9	Seaford	Sussex	0.1
DE14	DE 20 East, just past US 9	Seaford	Sussex	0.1

Table 2-2: Daily Measurements

Date	SDM	Site	Start	End	Active Hours	Beam Blocks	Valid Emissions and Speed	Valid %
14-Nov-11	4620	DE13	5:31:13 AM	10:38:12 AM	5.1	681	346	51%
14-Nov-11	4620	DE14	1:43:04 PM	4:28:44 PM	2.8	434	295	68%
15-Nov-11	4620	DE10	5:53:15 AM	5:40:41 PM	11.8	5,956	3,427	58%
16-Nov-11	4620	DE09	7:01:27 AM	9:30:48 AM	2.5	906	398	44%
17-Nov-11	4620	DE12	5:35:58 AM	6:01:35 PM	12.4	3,048	874	29%
18-Nov-11	4620	DE05	5:29:59 AM	7:00:19 PM	13.5	3,630	2,702	74%
21-Nov-11	4620	DE01	12:50:19 PM	5:45:11 PM	4.9	2,117	1,765	83%
21-Nov-11	4620	DE11	9:30:28 AM	11:45:03 AM	2.2	1,045	323	31%
22-Nov-11	4620	DE03	9:46:45 AM	12:19:56 PM	2.6	1,437	1,193	83%
23-Nov-11	4620	DE05	7:07:01 AM	6:16:49 PM	11.2	2,516	1,810	72%
25-Nov-11	4620	DE03	9:31:43 AM	3:16:21 PM	5.7	3,394	3,095	91%
Total					74.7	25,164	16,228	64%

FIGURE 2-2 SITE LOCATIONS IN DELAWARE



2.3.1 WEATHER CONSIDERATIONS

Rain, dense fog, and wet pavement resulting in spray from tires all prevent effective operation of the remote sensing unit since the beam is partially blocked under these conditions. Similarly, cold humid conditions that cause condensation of exhaust plumes are also not productive.

2.4 SOURCES OF DATA AND DESCRIPTION OF ELEMENTS

Data used in the analyses in this report come from two primary sources; the RSD unit measurements and the vehicle registration records.

The following description gives a summary of the main tables and data used in the analyses.

2.4.1 RSD MEASUREMENTS

For each measurement record the following information is collected:

RSD unit

Date and time

License plate image

HC, CO, CO₂, and NO measurement

Speed and acceleration

Temperature, barometric pressure, and humidity

Measurement quality indicators: V-valid, X-invalid, E-invalid system exception, O-invalid other, N-NO out of range, S-suspect

Ambientsⁱ

2.4.2 DATA COLLECTION STATISTICS

Unit

Site

Date

Start time

End time

ⁱ Ambient background levels of HC, CO, CO₂ and NO emissions are measured continuously and are deducted from the emissions levels measured in exhaust plumes of passing vehicles.

2.4.3 VEHICLE REGISTRATION DATA

The license plates of vehicles with Delaware plates measured by RSD were matched by plate to registration records provided by the department to determine the vehicle identification number (VIN) and additional vehicle information, e.g.:

Vehicle identification number (VIN)

Vehicle license plate

Fuel Code

Model year

Make

Body style

EPA vehicle type (LDGV, LDGT1, etc)

County

Zip code

2.5 DATA SCREENING

Envirotest applied the following screening checks to the RSD measurements to ensure the data used for fleet evaluation and fleet comparisons are reasonable and consistent:

- Screening of exhaust plumes
- Screening of hourly observations to check for cold starts;
- Screening of high values
- Screening of day-to-day variations in emissions values
- Screening for Vehicle Specific Power (VSP) range

The first four of these screening procedures are described in the following paragraphs. The VSP screening is described in section 3.2.

2.5.1 SCREENING OF EXHAUST PLUMES

The RSD4600 unit takes many measurements of each exhaust plume in the one half second after each vehicle passes the equipment.

The basic gas record validity criteria applied are:

- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO₂ and CO gas exceed 10%-cmⁱ; or
- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO₂ and CO gas exceed 5%-cm and the background gas values are very stable (not changing faster than a specified rate) at the time the front of the vehicle breaks the measurement beam.

2.5.2 SCREENING OF HOURLY OBSERVATIONS

Envirotest is concerned about vehicles operating in cold start mode or under conditions when exhaust plumes condense to steam. Vehicles measured under these conditions could appear to have high emissions without any emission system problems. To investigate this possibility, Envirotest tabulated for each site and hour the percentage of 2006 and newer vehicles that exceeded 250 ppm HC. The percent of 2006 and newer vehicles that exceed 250 ppm HC is normally low unless temperatures are below 40F when vehicles can trail steam plumes. Anomalies were observed in the percentages of 2006 and newer vehicles that exceeded 250 ppm HC in the early morning of November 16th and on November 22nd. There may have been light rain early on the 16th and measurements made between 7:00 am and 8:00 am were excluded from the emissions analysis. Light rain started in the morning of November 22nd and continued all day. This clearly affected HC values on the 22nd and measurements for the day were discarded. Average hourly temperature and relative humidity at the RSD van are shown in tables 2-4 and 2-5.

Measurements were also screened for the presence of unusually high values or unusually low values and none were identified.

Table 2-3: Percentage of 2006 and Newer Models with HC > 250 ppm

Day	RSD Unit	Site	5	6	7	8	9	10	11	12	13	14	15	16	17	18
21-Nov-11	__07064620	DE01									0%	0%	2%	1%	1%	
22-Nov-11	__07064620	DE03					4%	11%	7%	10%						
25-Nov-11	__07064620	DE03					0%	0%	0%	0%	0%	1%	0%			
18-Nov-11	__07064620	DE05	0%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
23-Nov-11	__07064620	DE05			0%	0%	0%	0%	0%	0%	0%	0%		1%	0%	
16-Nov-11	__07064620	DE09			5%	0%	0%									
15-Nov-11	__07064620	DE10		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
21-Nov-11	__07064620	DE11						0%								
17-Nov-11	__07064620	DE12				0%	0%					0%	0%	0%	0%	
14-Nov-11	__07064620	DE13			0%		0%									
14-Nov-11	__07064620	DE14										0%	0%			

ⁱ The unit of measurement 10%-cm is a measurement of the amount of a gas in the optical path. In this case, if all the molecules of the gas in the path were collected together into just one centimeter of the path then the concentration of the gas in the one-centimeter would be 10%.

Table 2-4: Hourly Temperature

Day	Unit	Site	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
21-Nov-11	__07064620	DE01								19	20	24	24	24	24		
22-Nov-11	__07064620	DE03					14	15	15	15							
25-Nov-11	__07064620	DE03					16	21	26	29	27	25	25				
18-Nov-11	__07064620	DE05	8	10	13	13	10	12	14	15	17	19	23	18	19	18	17
23-Nov-11	__07064620	DE05			21	25	24	25	19	18	17	16	13	13	12	12	
16-Nov-11	__07064620	DE09			19	20	21										
15-Nov-11	__07064620	DE10	20	21	23	24	24	25	27	27	27	27	27	26	25		
21-Nov-11	__07064620	DE11					15	15	16								
17-Nov-11	__07064620	DE12	13	12	11	9	10	9			9	10	10	9	8	7	
14-Nov-11	__07064620	DE13	15	15	16	18	19	21									
14-Nov-11	__07064620	DE14									26	25	24	23			

Table 2-5: Hourly Relative Humidity

Date	Unit	Site	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
21-Nov-11	__07064620	DE01								46	44	39	36	35	35		
22-Nov-11	__07064620	DE03					69	68	69	69							
25-Nov-11	__07064620	DE03					44	39	31	26	25	25	25				
18-Nov-11	__07064620	DE05	36	31	29	26	28	26	23	23	21	20	18	20	23	24	23
23-Nov-11	__07064620	DE05			69	57	57	56	68	66	65	66	67	65	62	57	
16-Nov-11	__07064620	DE09			67	63	62										
15-Nov-11	__07064620	DE10	60	59	53	50	50	49	44	43	41	42	41	39	40		
21-Nov-11	__07064620	DE11					69	66	61								
17-Nov-11	__07064620	DE12	67	63	60	64	59	58			62	54	49	45	40	41	
14-Nov-11	__07064620	DE13	69	70	68	60	56	50									
14-Nov-11	__07064620	DE14									40	41	44	47			

2.5.3 SCREENING OF DAY-TO-DAY VARIATIONS IN EMISSIONS VALUES

Day-to-day decile values were compared for 2006 and newer vehicles. Only a small percentage of these vehicles are expected to have high emissions and we expect the intermediate decile emission values should not vary significantly from day-to-day, from site-to-site or between RSD units. In Figure 2-3, the HC decile values for each day of measurements are plotted side-by-side as an example. This comparison revealed median values for the 2006 and newer models that ranged day-to-day from -1 ppm to -25ppm. Although these variations are within the HC specification of the RSD4600 units they are significant compared to average fleet emissions for newer vehicles.

The most likely explanation is that the variation in daily medians represents the limits of accuracy in the daily instrument set-up. For HC, an adjusted set of values was created by direct addition or subtraction of a daily offset that would set the daily median values to zero. We believe this is appropriate since the median I/M test result for new models is normally zero or very close to zero. The results of the correction are shown in Figure 2-4 and analyses shown later in this report used the adjusted HC values.

Day-to-day decile CO, NO and UV smoke values for 2006 and newer vehicles are shown in Figures 2-5 to 2-7. Median values for CO, NOx and smoke were 0.02%, 6ppm and 0.02 respectively. These small positive and zero values appear reasonable and adjustments were not applied to these pollutants.

FIGURE 2-3 DAILY HC DECILES

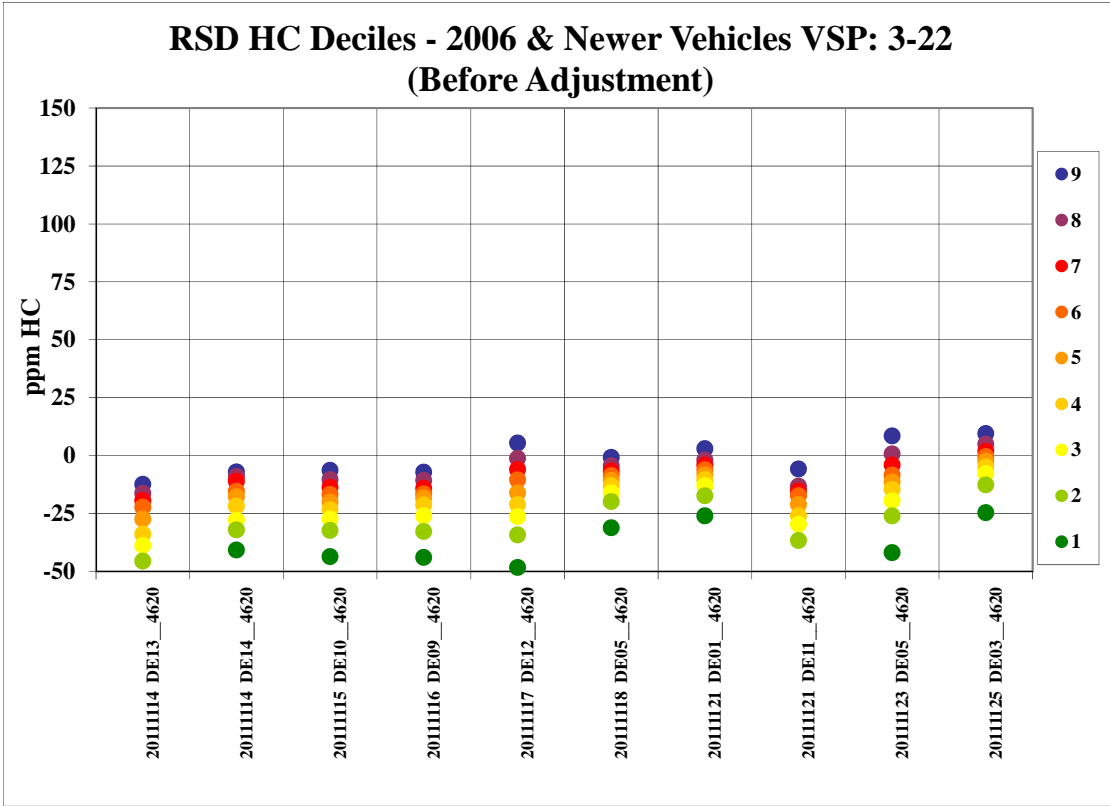


FIGURE 2-4: DAILY HC DECILES - AFTER ADJUSTMENT

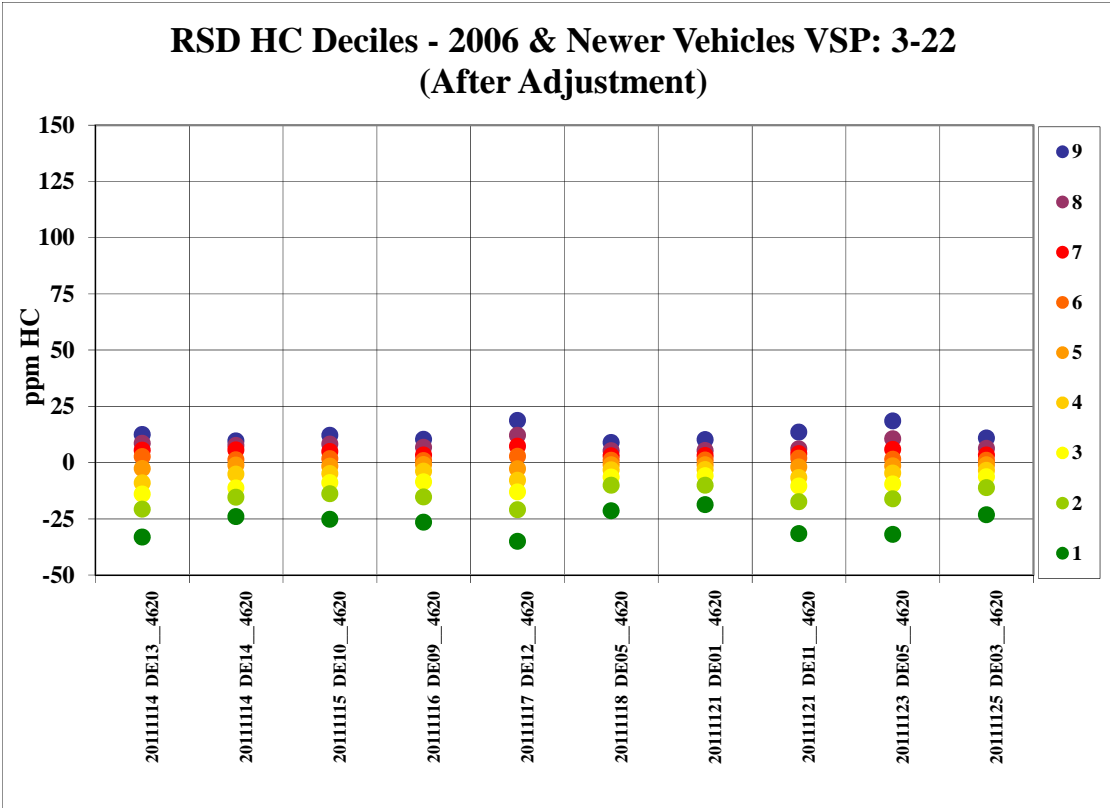


FIGURE 2-5 DAILY CO DECILES

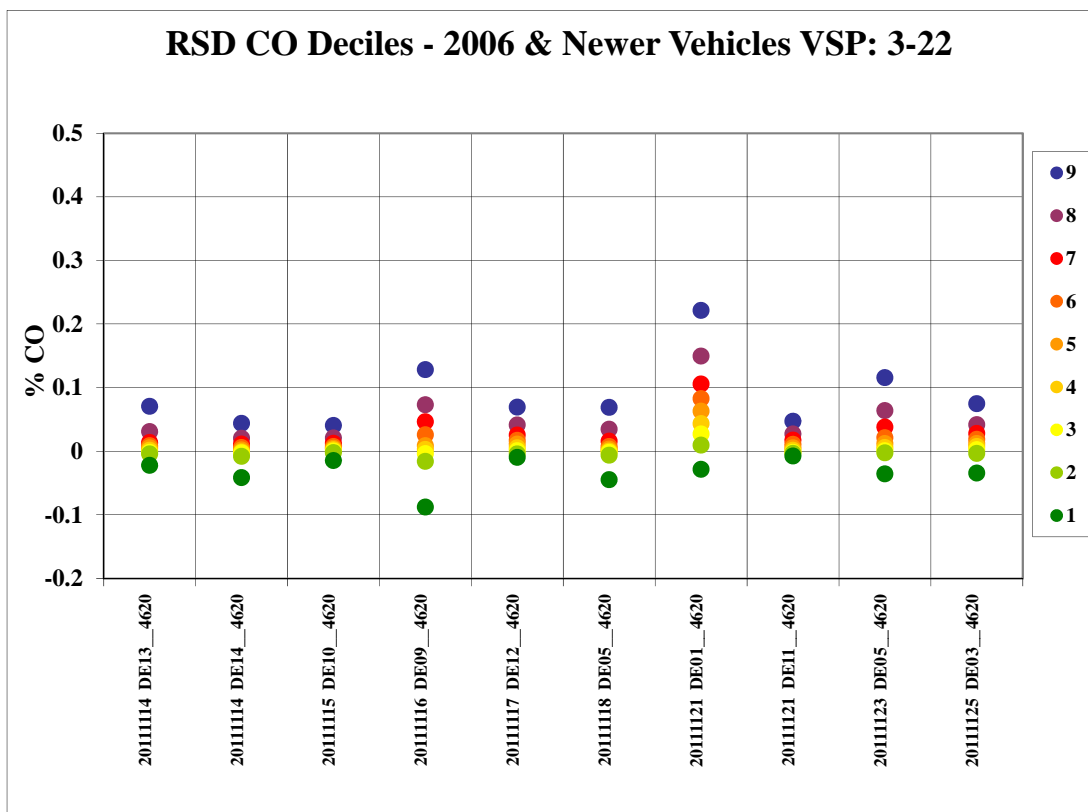


FIGURE 2-6 DAILY NO DECILES

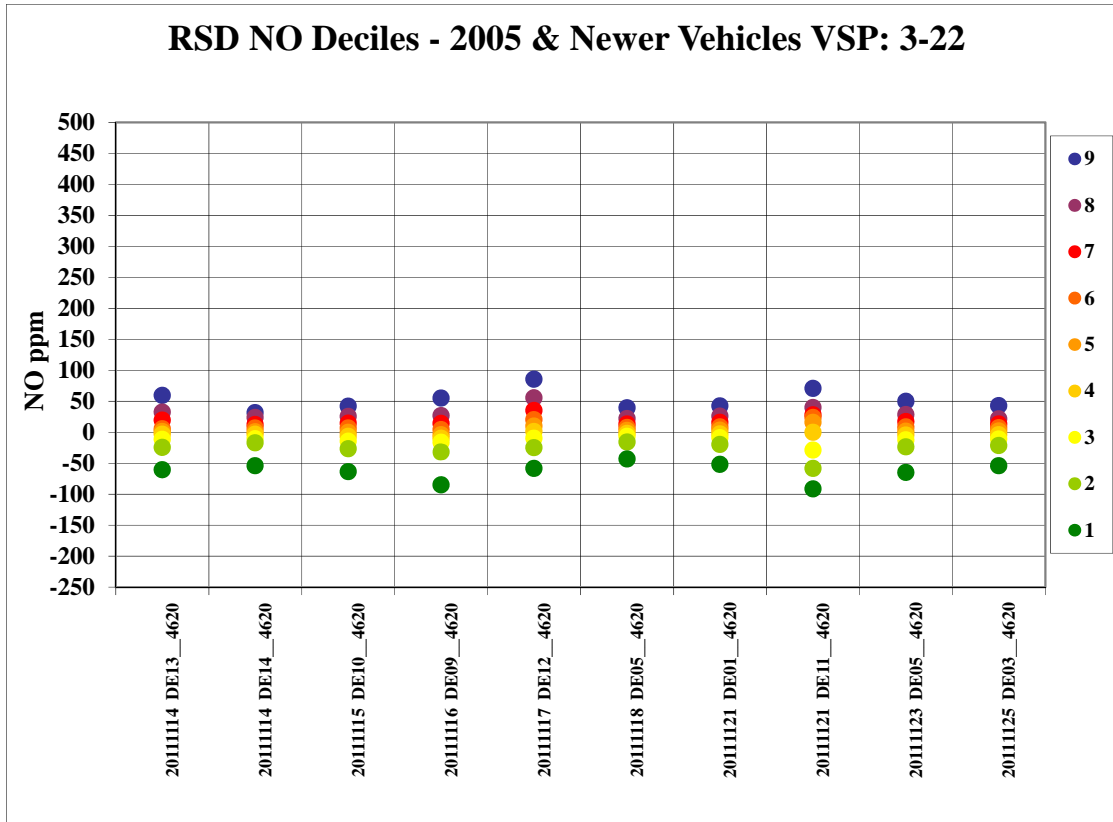
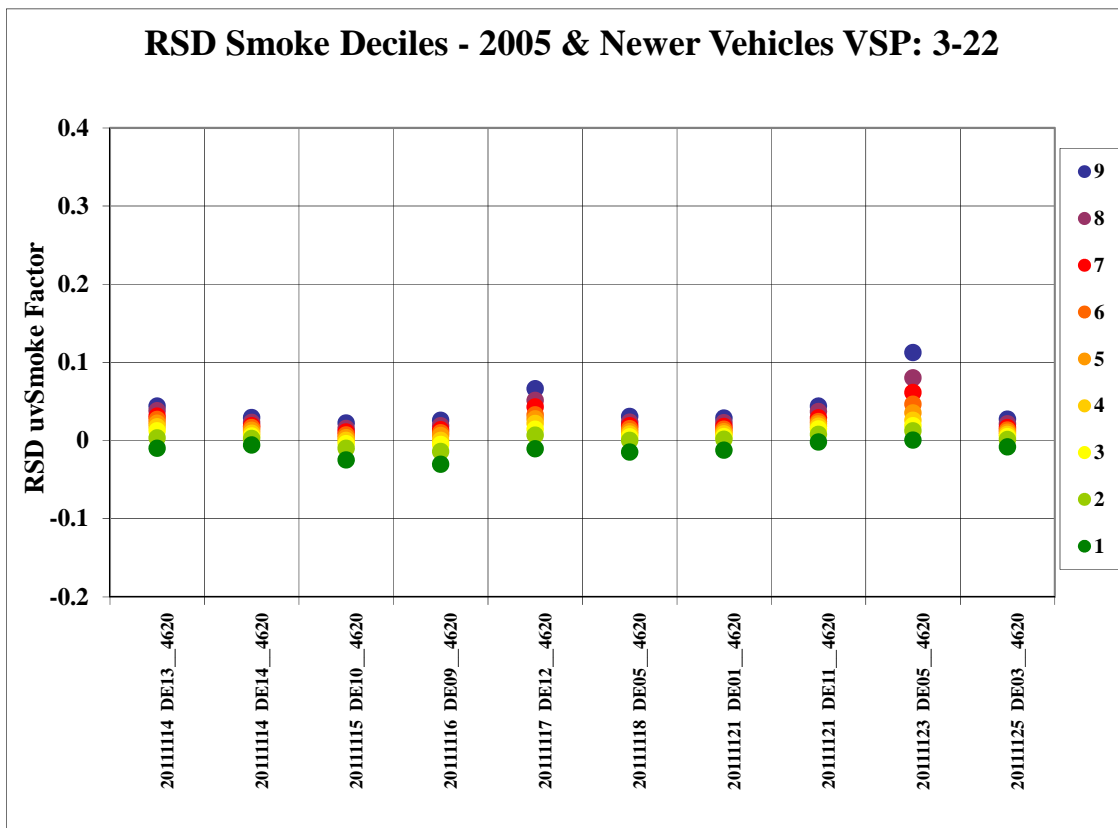


FIGURE 2-7 DAILY SMOKE DECILES



3. ANALYSIS OF DATA COLLECTED

3.1 STATISTICS AND RSD COVERAGE

The study data collection phase lasted from November 14th through November 25th using RSD4600 system 4620.

Table 3-1 shows the remote sensing measurements made during nine calendar days of testing in Delaware. Approximately 13,000 measurements were made with complete information (speed, acceleration, emission measurements and a plate).

Table 3-2 shows the number of vehicles registered within Delaware and neighboring states. Eight-four percent of vehicles measured at the survey locations were registered in Delaware, 5% were from Pennsylvania, 4% from Maryland, 3% from New Jersey, 1% from Virginia and 2% other states.

Table 3-1: Number of Remote Sensing Records by License Plate

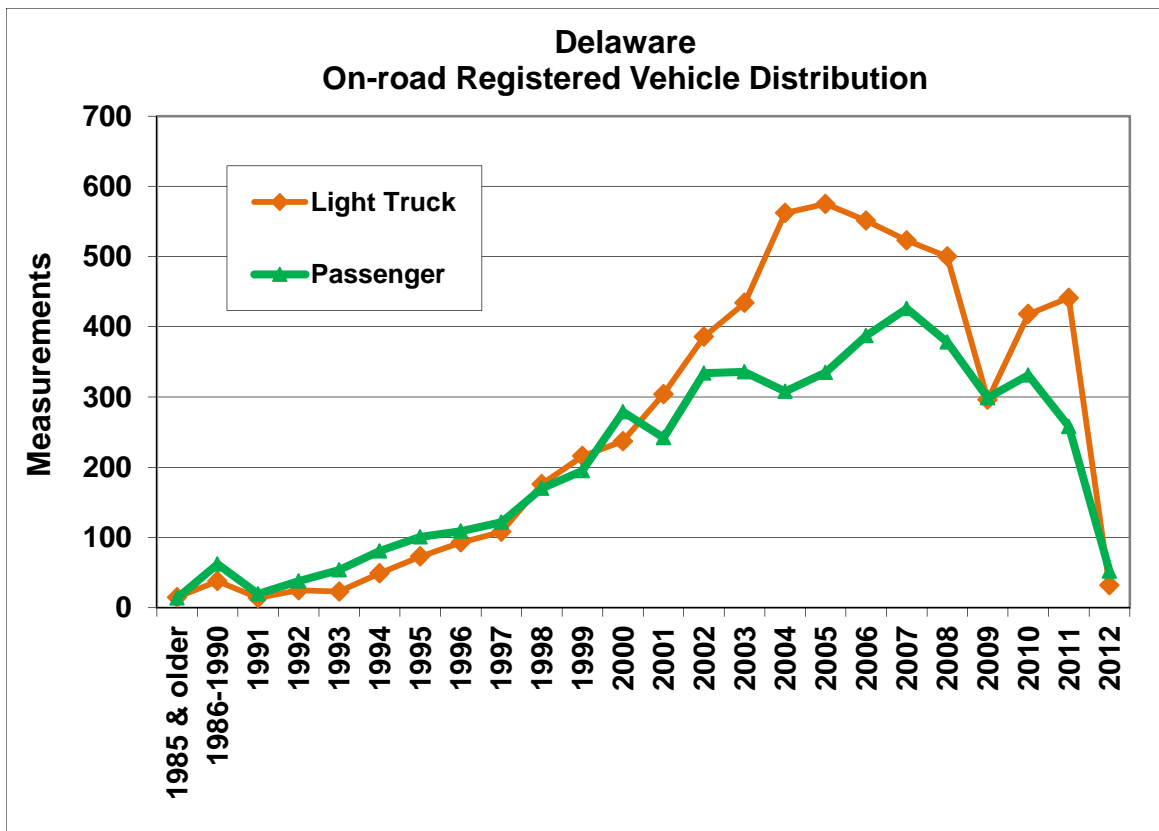
RSD Units	1
Sites	9
Collection-Days	9
Attempted Measurements	25,164
Valid Measurements	15,739
With Valid readings within 3-22 kw/t & Visible Plate	13,266
- Other State Plates	2,177
- Delaware Plates	11,089
Matched to Delaware Registrations	11,029
Unique Delaware Vehicles Identified	10,212
Unique Delaware Vehicles Identified Once	9,468
Unique Delaware Vehicles Identified Twice	680
Unique Delaware Vehicles Identified Three Times	57
Unique Delaware Vehicles Identified Four or More Times	7

Table 3-2: Valid Remote Sensing Records by State Plate

State	Count	%
Delaware	11,089	84%
Maryland	521	4%
New Jersey	460	3%
New York	72	1%
Pennsylvania	719	5%
Virginia	147	1%
Other	258	2%
Total	13,266	100%

Figure 3-1 shows the distribution of the vehicles measured on-road and registered in Delaware that were matched to registration information. The on-road distribution tends to be more skewed towards newer vehicles than the number of registrations. This is because, 1) newer vehicles are more active and 2) there are more 'dead' DMV records of older vehicles. For 2002 through 2008 models there were more light trucks than passenger vehicles. The overall numbers of 2009 models observed was low compared to 2002 to 2008 models reflecting the impact of the recession on 2009 model vehicle sales – especially sales of light trucks.

FIGURE 3-1 MODEL YEAR FRACTIONS OF ON-ROAD LIGHT VEHICLES IN DELAWARE



3.2 VEHICLE SPECIFIC POWER

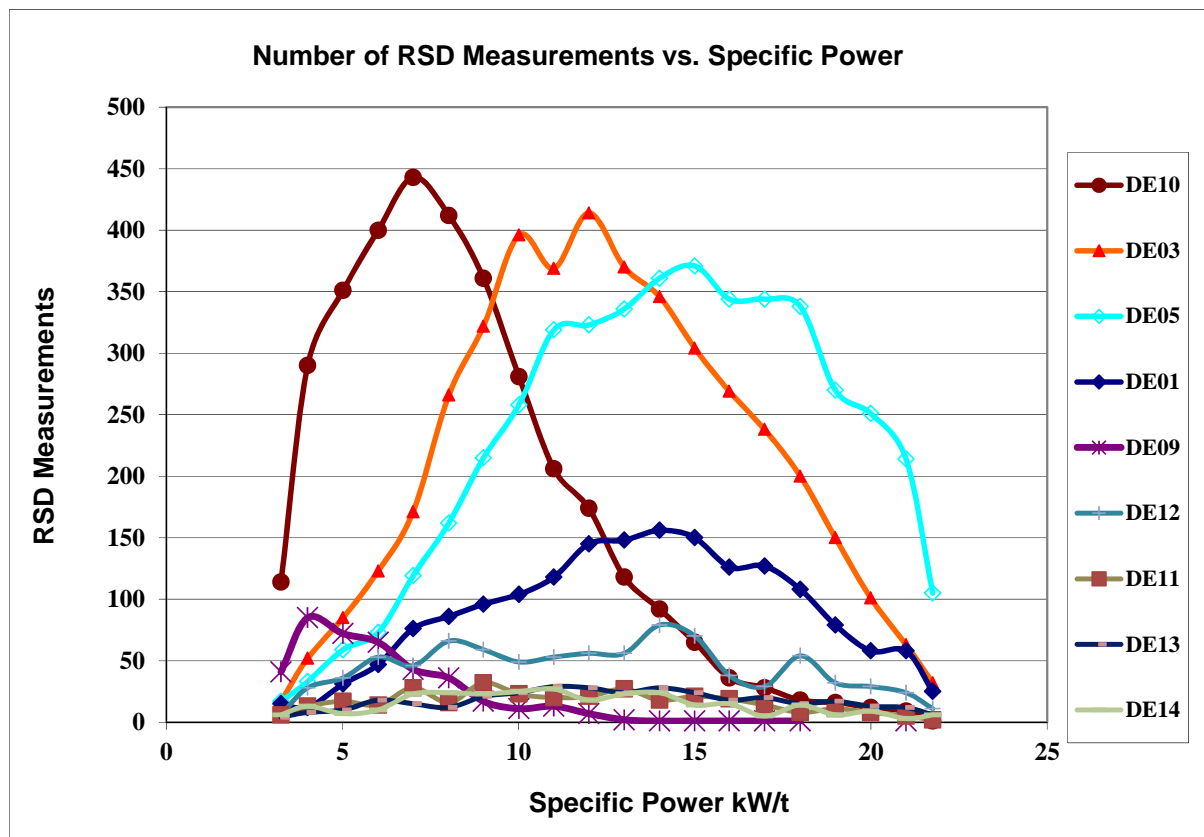
Envirotest used the speed/acceleration and site grade data to determine Vehicle Specific Power (VSP). VSP attempts to normalize the power requirements of the vehicle based upon speed, acceleration and slope at the site. VSP is defined by the following equation:

$$\text{VSP} = 4.364 * \sin(\text{Grade in Deg}/57.3) * \text{Speed} + 0.22 * \text{Speed} * \text{Accel} + 0.0657 * \text{Speed} + 0.000027 * \text{Speed} * \text{Speed} * \text{Speed}$$

Measurements where VSP was between 3 and 22 kW/t were used in subsequent analyses.

Figure 3-2 shows the distribution of VSP at each site. A majority of observations fell within the range of 3 to 22 kW/t, which are considered to be valid readings by Envirotest for program evaluation. Measurements outside of the desired VSP window were not included.

FIGURE 3-2: DISTRIBUTION OF VSP AT SITES



3.3 VEHICLE FLEET EMISSION RATES

3.3.1 EMISSION BY JURISDICTION

Envirotest calculated average hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO) emission rates of vehicles registered in Delaware and other states.

Table 3-3 and Figures 3-3 to 3-5 compare emissions of vehicles registered in Delaware to those driving in Delaware but registered in other states. Vertical bars on the charts indicate the 95% confidence intervals for emissions values. As noted in Table 3-3, samples of measurements of out-of-state vehicles observed in Delaware were relatively small and this resulted in wide confident intervals that overlap. Thus differences in mean emissions were not statistically significant. Overall, HC and CO emissions of vehicles with out-of-state plates were 15% and 12% lower than Delaware plates and NO emissions of vehicles with out-of-state plates were 13% higher.

Also shown in Table 3-3 are emissions of 597 vehicles identified as trucks and four motorcycles. The trucks had three times higher HC, NO and smoke emissions than light vehicles.

Table 3-3 Mean Emissions by Jurisdiction

Name	N	CO %	HC ppm	NO ppm	RSD UV Smoke	VSP kw/t
Delware Plates	11,089	0.13	19	183	0.027	12.1
Other State Plates:						
Maryland	521	0.13	22	251	0.036	11.9
New Jersey	460	0.12	15	158	0.031	12.6
New York	72	0.06	19	124	0.049	13.8
Pennsylvania	719	0.12	17	236	0.033	13.2
Virginia	147	0.09	18	193	0.033	13.1
Other	258	0.07	7	164	0.033	12.6
Total Other States	2,177	0.11	16	208	0.034	12.7
Trucks	597	0.10	58	686	0.103	9.9
Motorcycles	4	1.81	90	1,325	0.169	15.6
Plate Not Readable	997	0.18	32	292	0.039	12.1
Total On-road	14,864	0.13	21	215	0.032	12.1

FIGURE 3-3: MEAN HC BY JURISDICTION

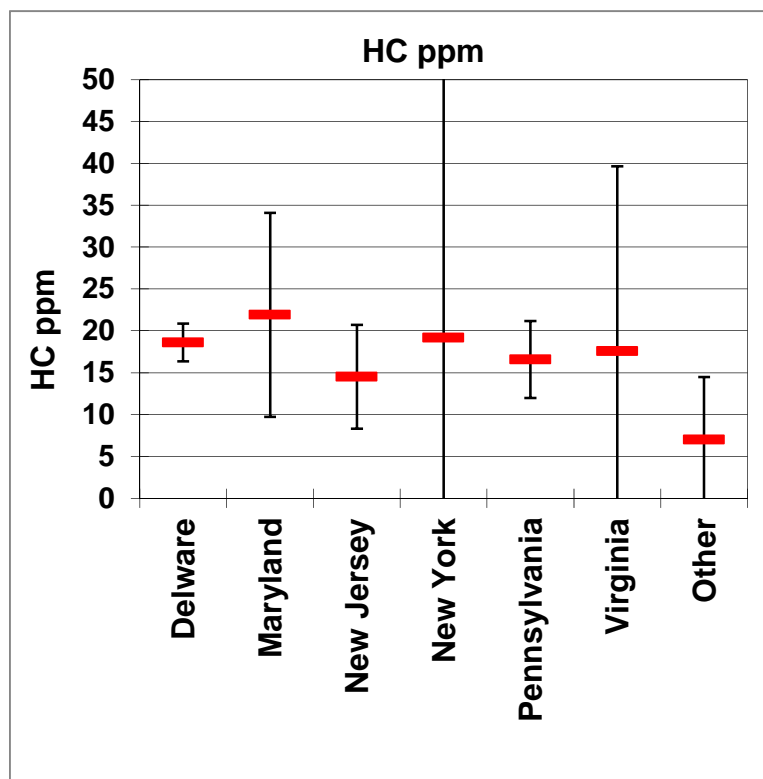


FIGURE 3-4: MEAN CO BY JURISDICTION

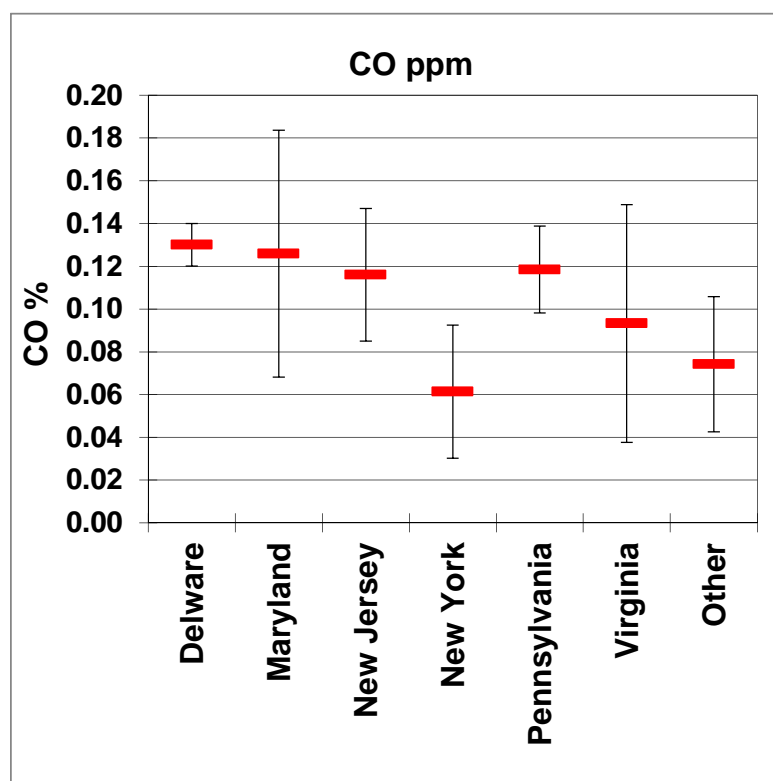


FIGURE 3-5: MEAN NO BY JURISDICTION

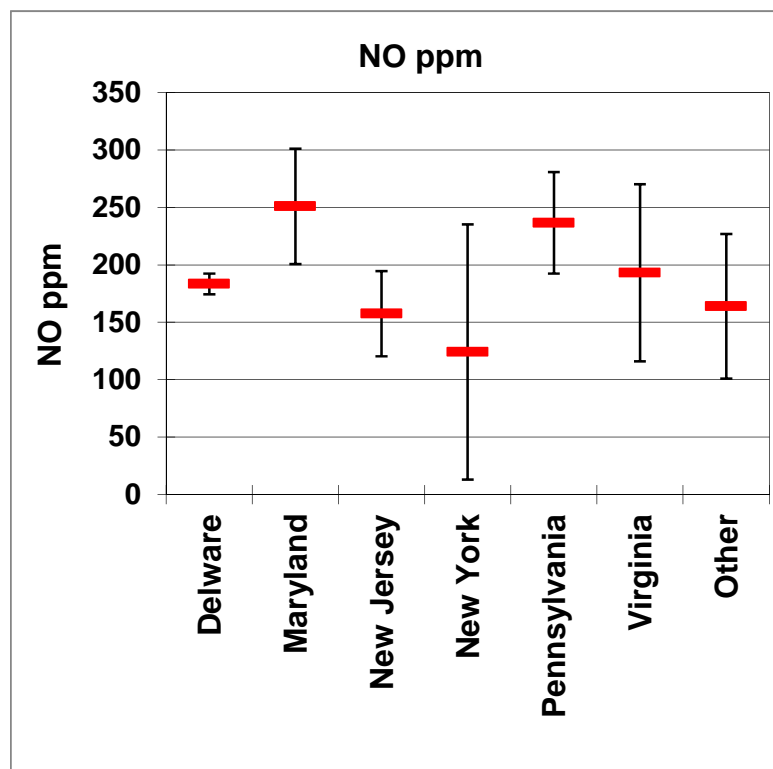
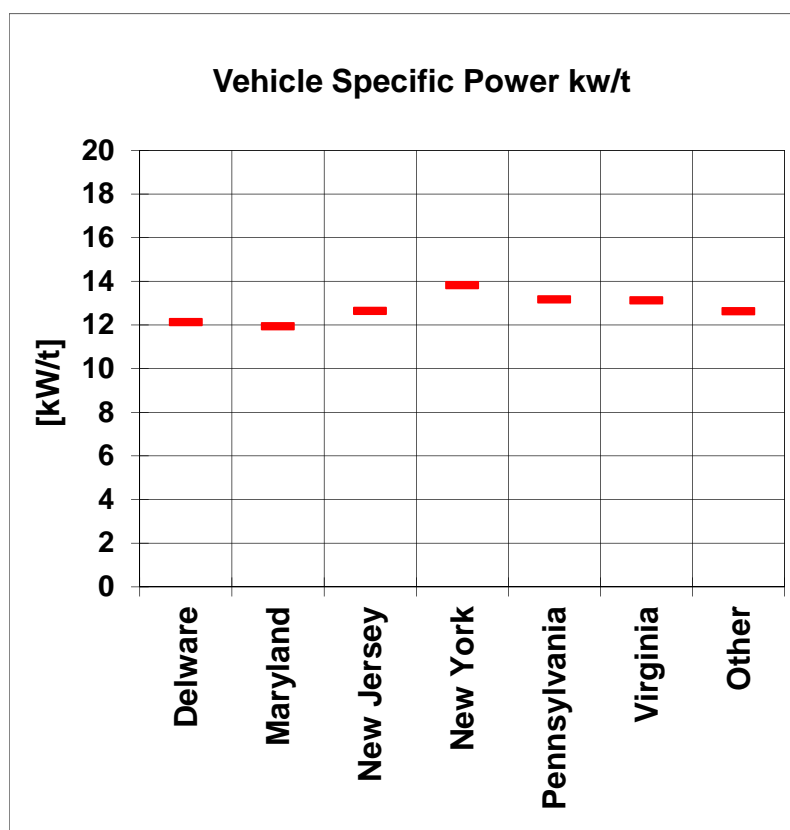


FIGURE 3-6: VSP VS. JURISDICTION



3.3.2 DELAWARE AVERAGE EMISSIONS BY MODEL YEAR

Average emissions by model year are shown in Figures 3-7 to 3-9. A number of vehicles have very high emissions that affect the average values for a particular vehicle type and model year. Thus, there is considerable variation in model year averages. On the whole, however, it is apparent that trucks have higher emissions than passenger vehicles of the same age – especially for NO.

A larger survey would allow more accurate assessment of the average emissions by year of passenger vehicles and light trucks.

FIGURE 3-7: AVERAGE HC EMISSIONS

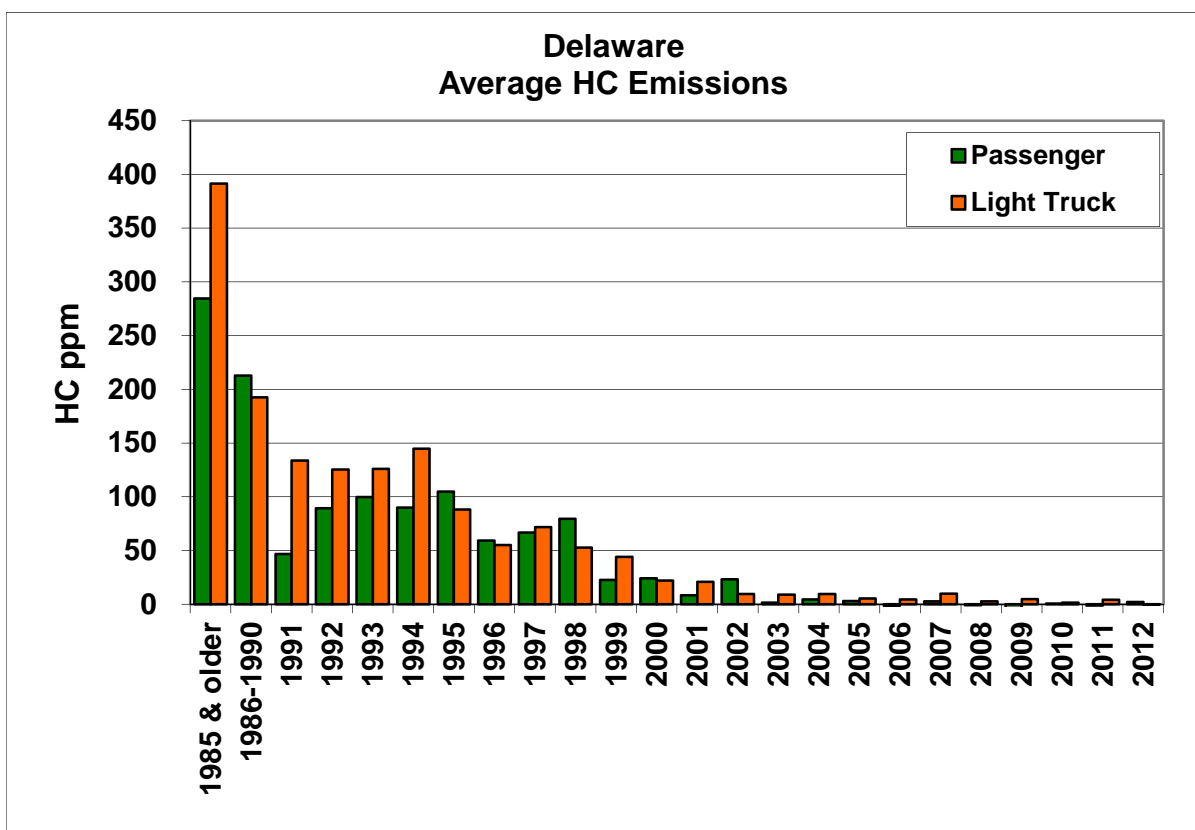


FIGURE 3-8: AVERAGE CO EMISSIONS

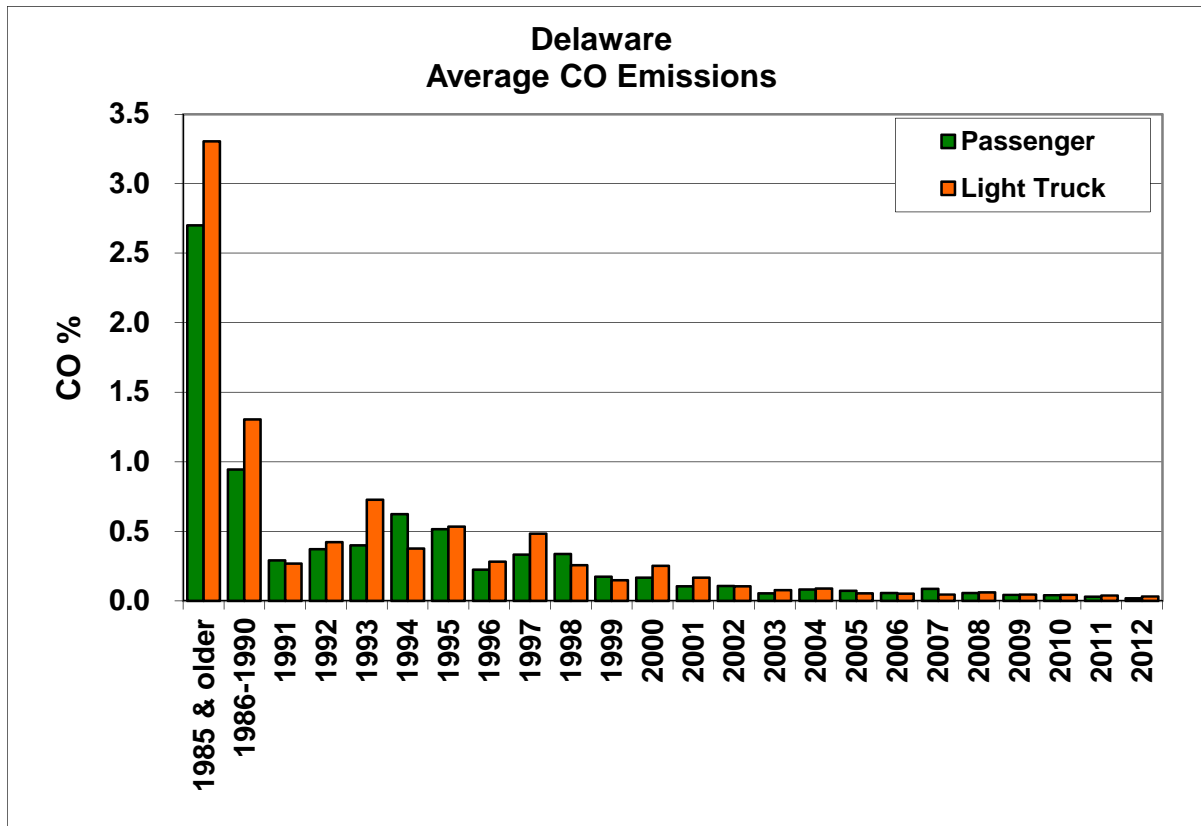
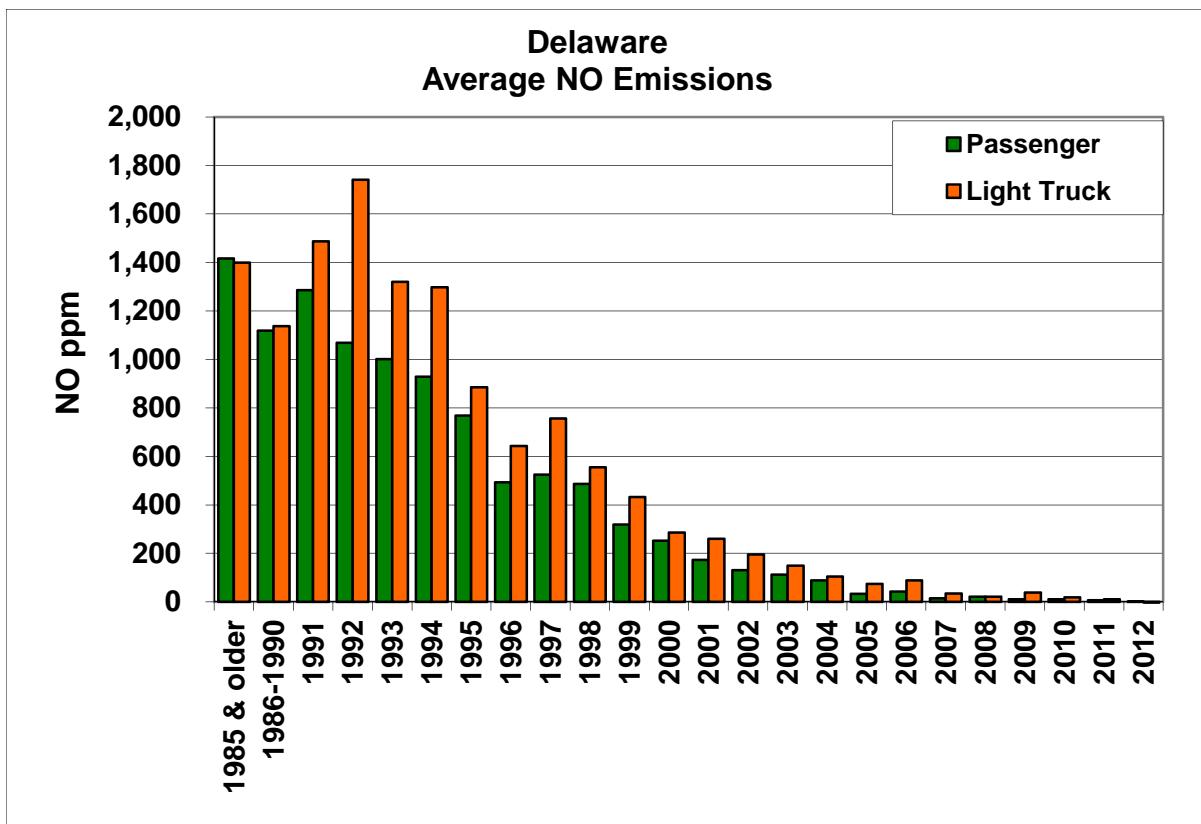


FIGURE 3-9: AVERAGE NO EMISSIONS



3.3.3 APPROXIMATE EMISSION CONTRIBUTIONS BY MODEL YEAR

Figures 3-10 through 3-13 illustrate the contributions to light vehicle VMT. The number of vehicle measurements is approximately representative of VMT. The exhaust emission contributions assume that each model year obtained the same miles per gallon and that passenger and truck fuel economies were 24 and 20 miles per gallon respectively. The American Automobile Manufacturers Association reports that the average combined import and domestic new car fuel economy increased from 25.9 in 1981 to 26.9 in 1984 and ranged between 27.6 and 28.8 mpg from 1985 through 1997. Therefore the assumption of constant fuel economy for each year is not far off. Lower values than reported are used because in-use experience has shown lower fuel economies than the earlier laboratory test based EPA ratings. Starting with 2008-model vehicles, the EPA adopted a new protocol for estimating the MPG figures presented to consumers. The new protocol included driving cycles more closely representative of today's traffic and road conditions, as well as increased air conditioner usage. The US Department of Transportation reported that Delaware consumed approximately 445 million gallons of gasoline and gasohol in 2008.

Contributions of on-road emissions were skewed towards the older vehicles. 1999 and older models accounted for 16% of on-road activity and for 70%, 51% and 61% of the HC, CO and NO emissions respectively. Therefore, it is important to maintain the effectiveness of I/M programs for the vehicles over ten years old that have emissions many times those of newer vehicles.

Light trucks contributed 55% of VMT and 57%, 56% and 60% of HC, CO and NO respectively.

FIGURE 3-10: APPROXIMATE VMT CONTRIBUTION

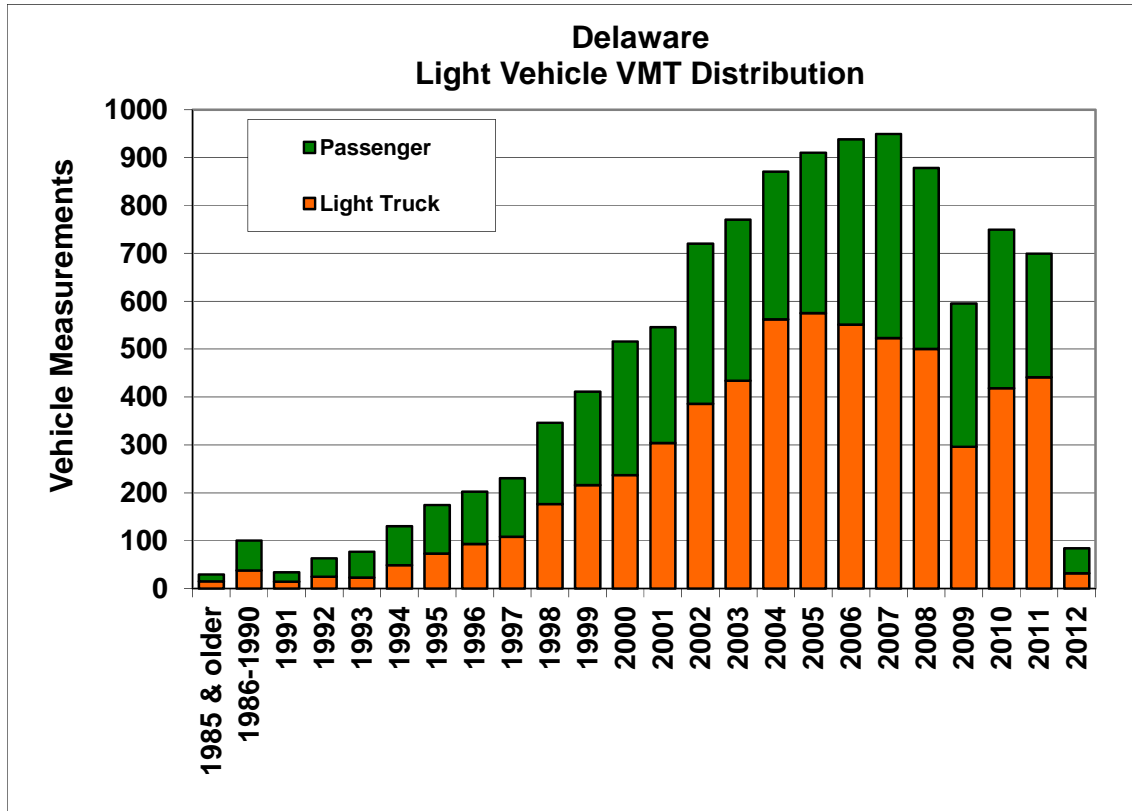


FIGURE 3-11: APPROXIMATE HC CONTRIBUTION

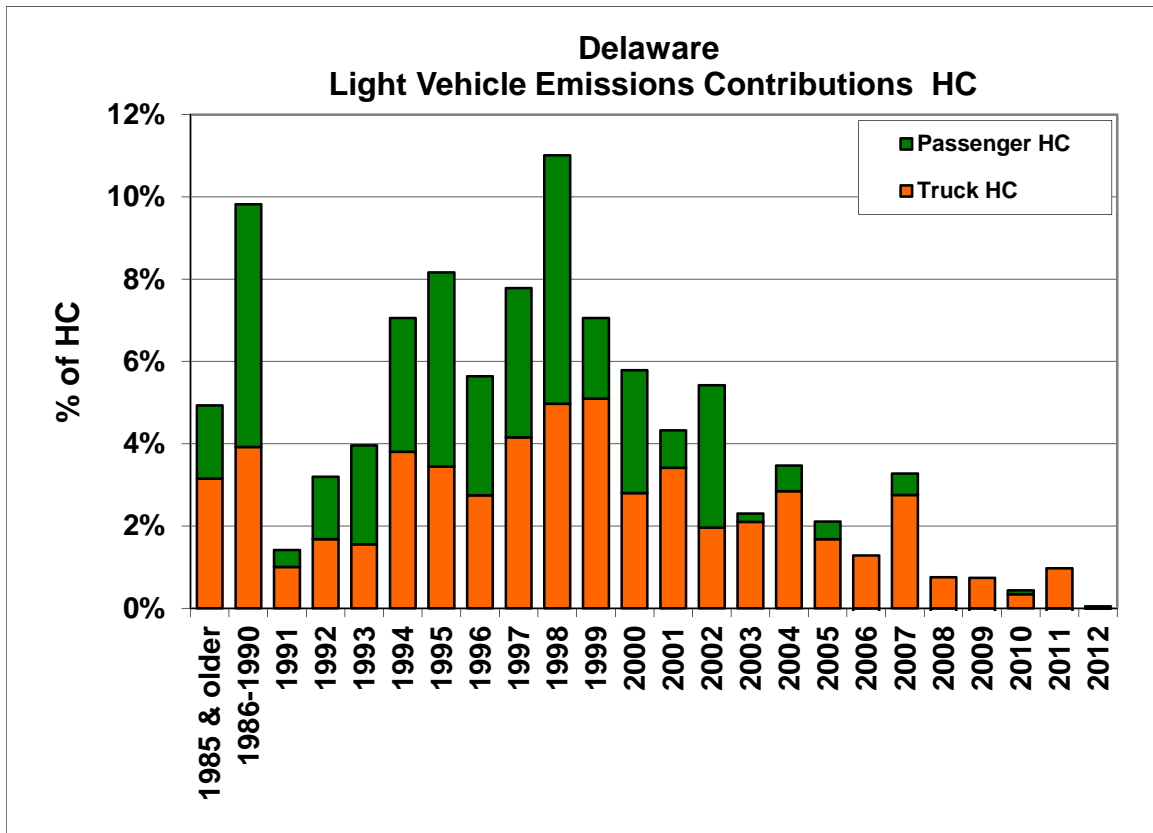


FIGURE 3-12: APPROXIMATE CO CONTRIBUTION

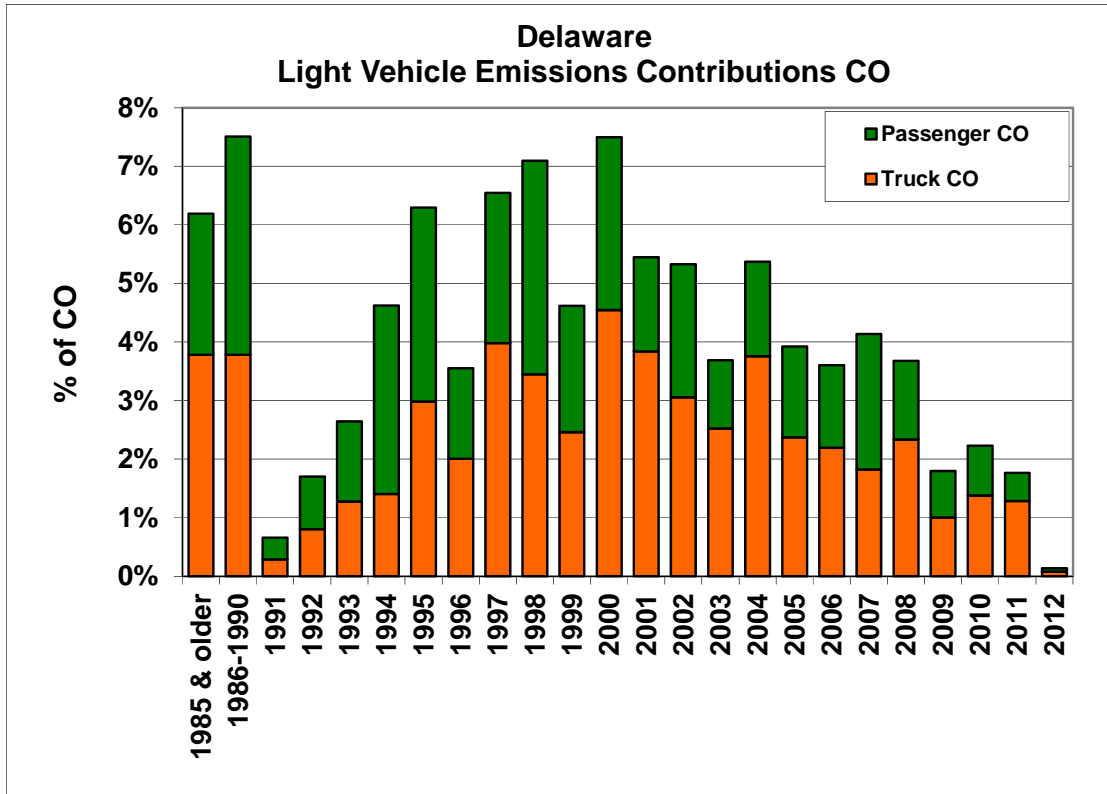
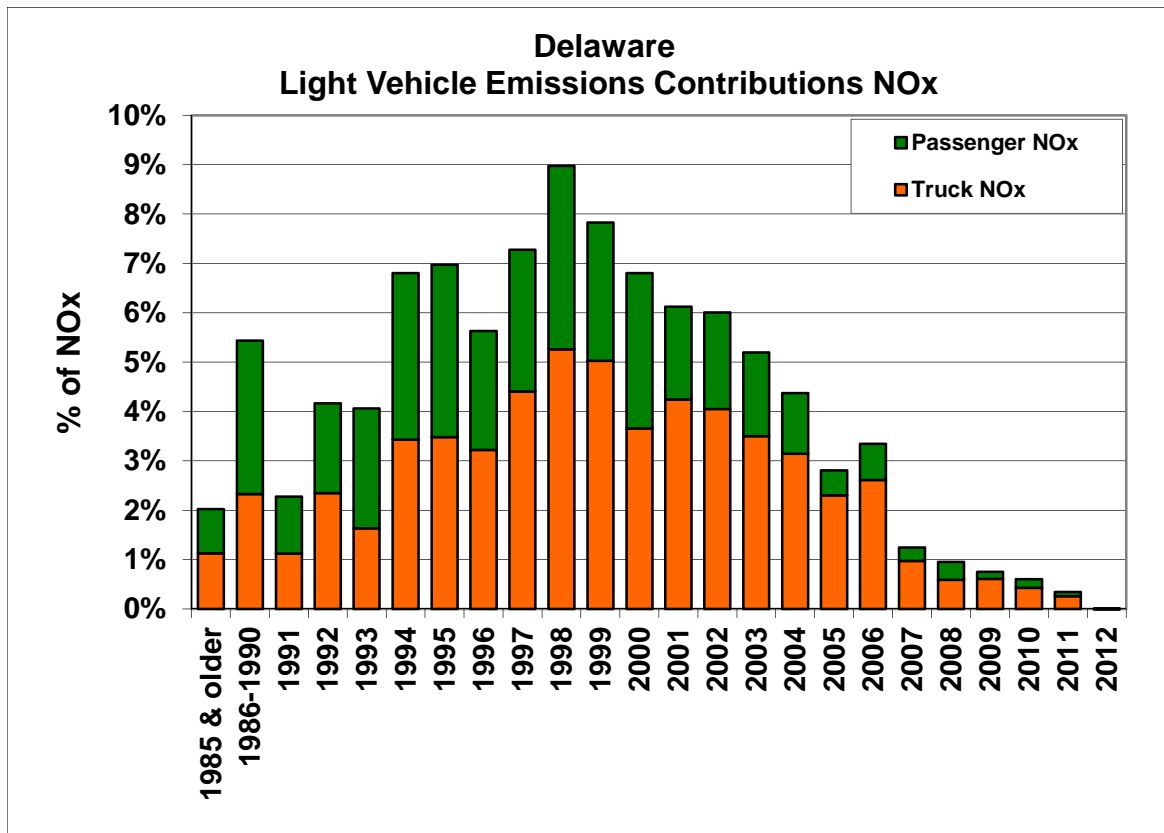


FIGURE 3-13: APPROXIMATE NOX CONTRIBUTION



4. HIGH EMITTERS

High emitters were identified using cutpoints of 500ppm HC, 3% CO, 2,000ppm NO and 0.75 RSD smoke factor. These definitions of high emitters are, admittedly, somewhat arbitrary and use higher values than the standards typically used in an inspection and maintenance program.

Of the vehicles measured on-road that were identified by plate and matched to a Delaware registration, 267 (2.6%) exceeded one or more of the pollutant cutpoints (Table 4-1). However, these 2.6% of vehicles had average emissions of 327ppm HC, 1.5% CO and 2,077 ppm NO – hundreds of times dirtier than the median vehicle. The 2.6% high emitting vehicles emitted up to 27%, 49% and 24% of all light vehicle CO, HC and NO.

Table 4-2 shows the combinations of cutpoints that were exceeded. With these cutpoints a majority of the vehicles identified as high emitters were selected for high NO.

A number of vehicles were identified for more than one pollutant. Almost 30% of vehicles with high HC also had high CO. Most vehicles with high NO did not have high emissions of another pollutant.

Table 4-1: High Emitters

	Count
Vehicles exceeding one or more cutpoints	267
Emissions cutpoints exceeded:	
HC 500 ppm hexane	46
CO 3%	53
NO 2000ppm	190
UV Smoke Factor 0.75	1
Total Cutpoints Exceeded	290

4.1 HIGH EMITTER CUTPOINTS VS. IN-USE STANDARDS

Figures 4-1 to 4-4 illustrate the relationship of the adopted RSD high emitter cutpoints to vehicle in-use standards. We only show standards through 2003 models. Standards for Tier 2 2004 and newer models are the same or lower.

The precise g/mi equivalents for RSD concentration emissions values depend on vehicle fuel economy. Typical average values of 24 mpg for light passenger vehicles and 20 mpg for light trucks were used in these Figures.

The selected high emitter cutpoints far exceed the in-use standards.

Table 4-2 Higher Emitters by Pollutant

HE Cutpoint Exceedance Combinations	Count
Single pollutant:	
HC Only	26
CO Only	38
NO Only	181
Smoke Only	-
Two Pollutants:	
HC & CO Only	12
HC & NO Only	6
CO & NO Only	1
HC & Smoke Only	2
CO & Smoke Only	-
NO & Smoke Only	-
Three Pollutants:	
HC & CO & NO	1
HC, CO & Smoke	-
HC, NO & Smoke	-
CO, NO & Smoke	-
Jackpot:	
HC, CO, NO & Smoke	-
Total	267

FIGURE 4-1 HIGH EMITTER HC VS. IN-USE STANDARDS

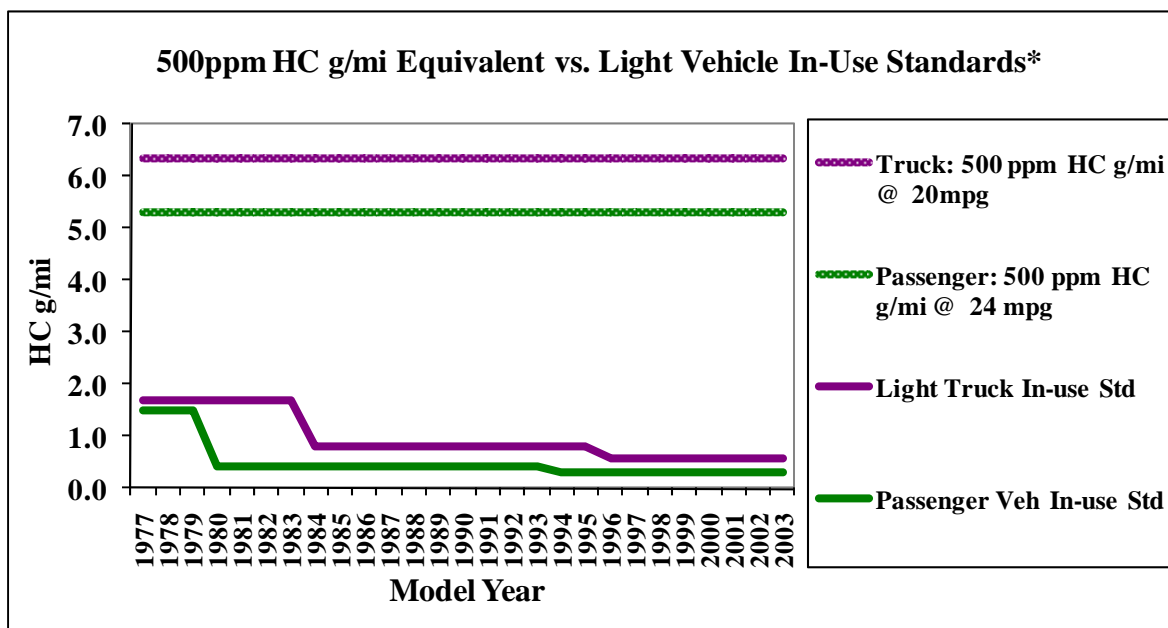


FIGURE 4-2 HIGH EMITTER CO VS. IN-USE STANDARDS

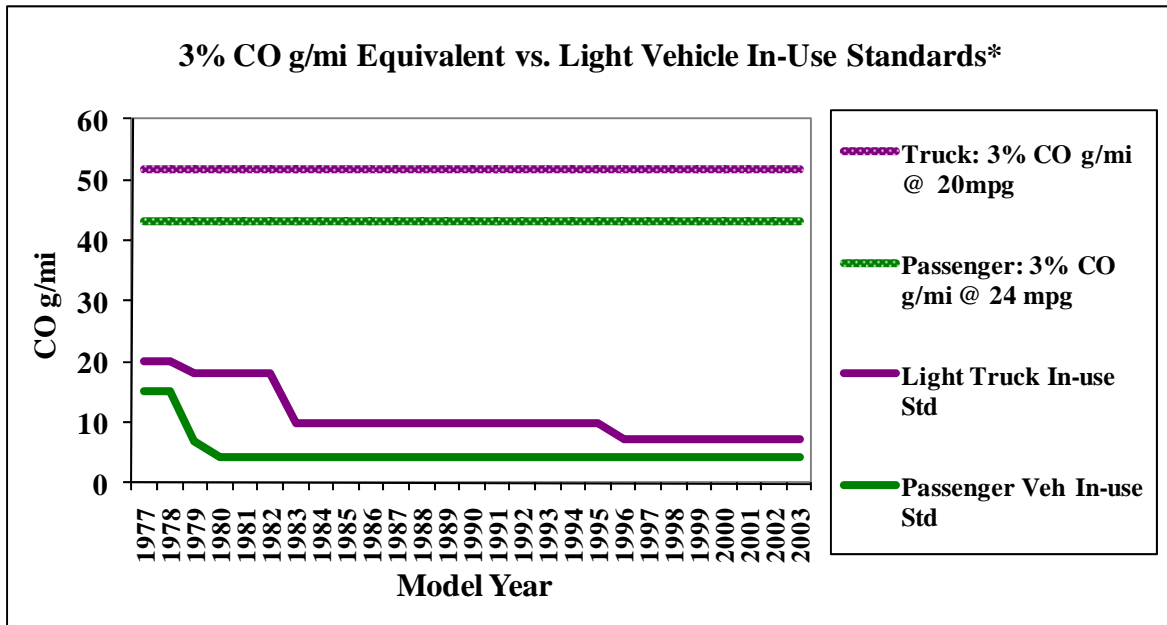


FIGURE 4-3 HIGH EMITTER NOX VS. IN-USE STANDARDS

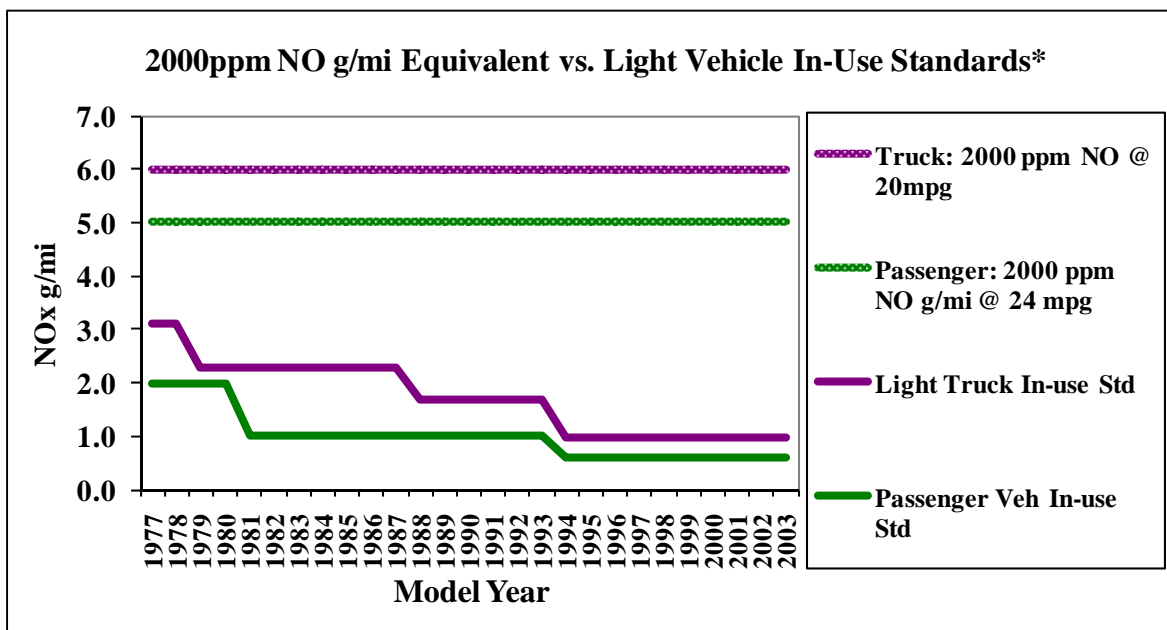
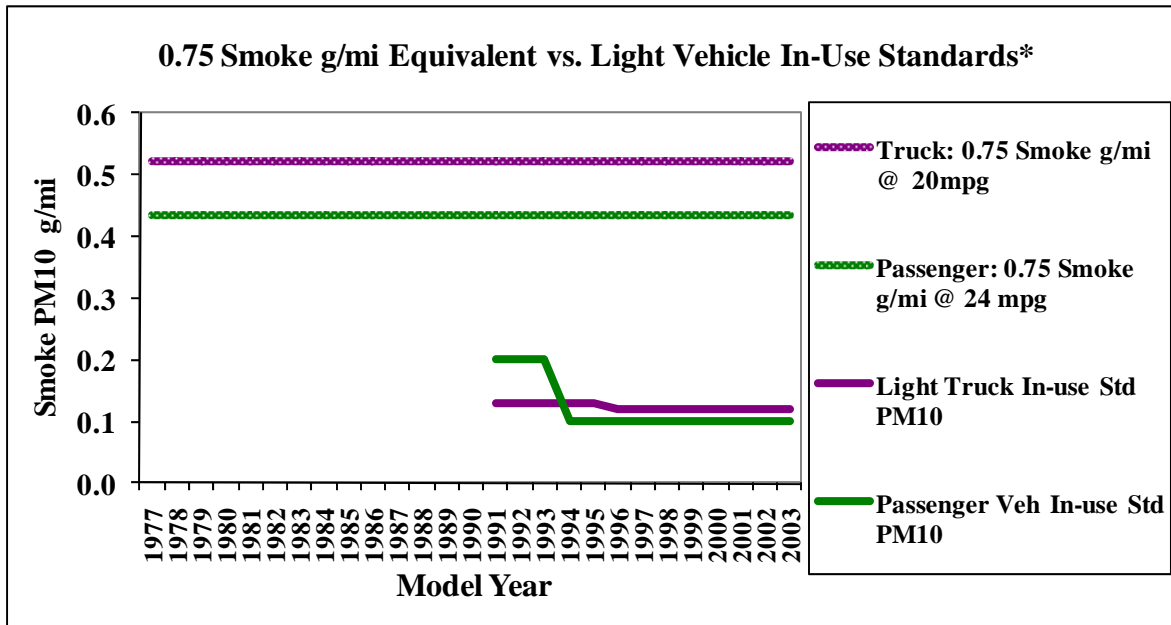


FIGURE 4-4 HIGH EMITTER VS. PM10 IN-USE STANDARDS



4.2 HIGH EMITTER RATES

High emitter rates varied dramatically by model year, with the oldest models having rates of over 50% and the newest models have rates of less than 0.1% (Figure 4-5). Fortunately, relatively few of the oldest models remain in operation. On a positive note, high emitter rates among models less than ten years old remained low – an average of 0.6% vs. 10% for older models. Manufacturers improved component quality considerably to meet OBD-II requirements. These improvements, combined with the engine warning light that alerts owners to emissions problems, are responsible for the low rates of high emitters observed in vehicles up to ten years old at the time of the survey.

Figure 4-6 shows the number of high emitters by model year. The greatest numbers of high emitters were 1992-2002 models. The lower numbers of 1996 model high emitters may be a random fluctuation. A larger dataset is required to confirm more precise rates of high emitters by model year. Two thirds of the high emitters were flagged only for high NO_x.

4.3 HIGH EMITTERS WITH MULTIPLE MEASUREMENTS

Table 4-3 lists RSD measurements for high emitters with two or three measurements. In all cases, vehicles exceeded one or more pollutants cutpoints on both measurements. For failing pollutants, these high emitters were 17 times, 24 times and 9 times dirtier for HC, CO and NO_x respectively than the average vehicle.

FIGURE 4-5: PERCENT OF HIGH EMITTERS BY MODEL YEAR

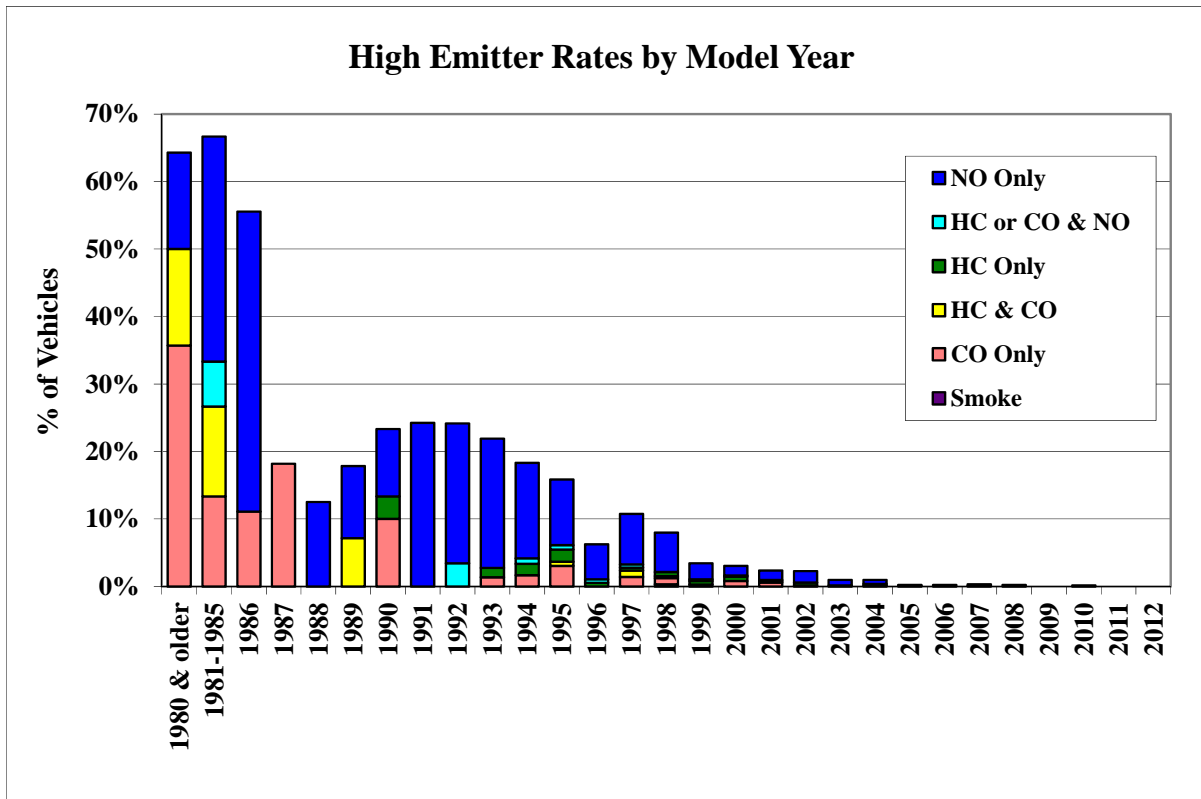


FIGURE 4-6: NUMBER OF HIGH EMITTERS BY MODEL YEAR

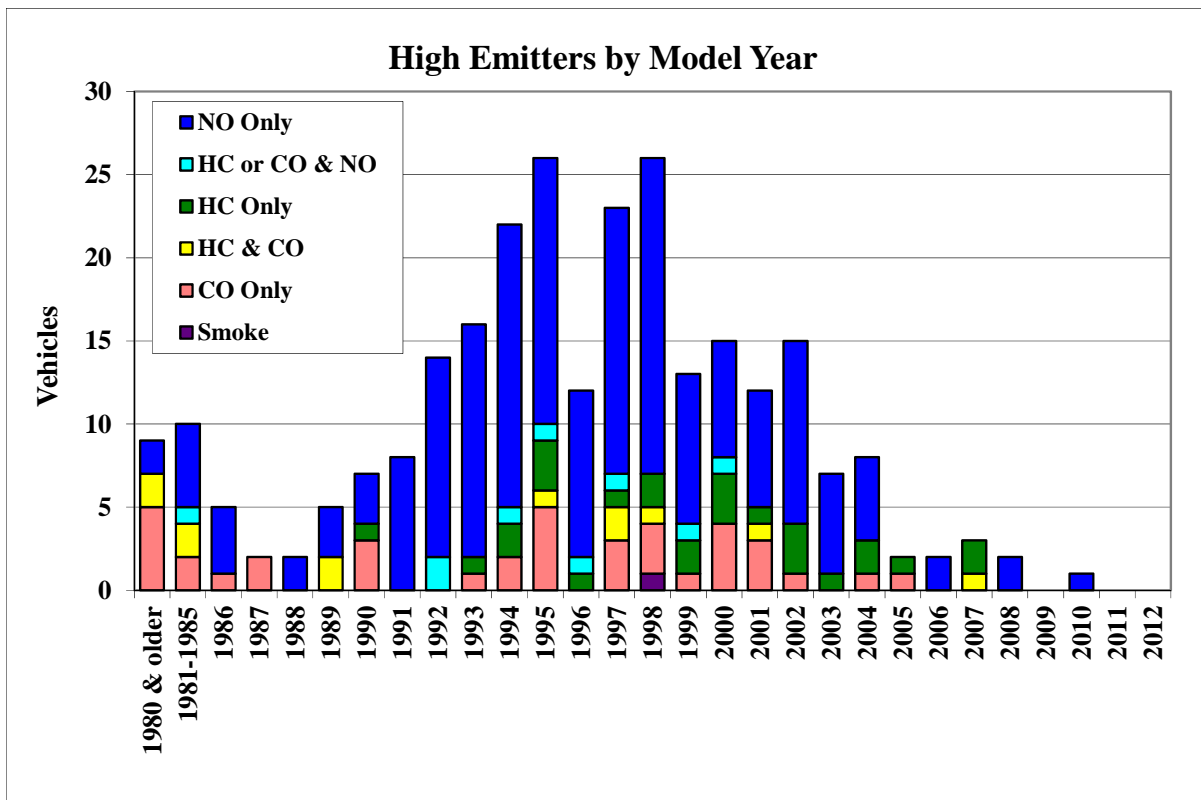


Table 4-3: High Emitters with Two Measurements

MY	Make	Mod	Fuel	HC Cutpoint	HC ppm	CO Cutpoint	%CO	NO Cutpoint	ppm NO	Smoke Cutpoint	uv Smoke
1984	FORD	BRO	G	500	619	3	5.5	2000	1006	0.75	0.24
1984	FORD	BRO	G	500	411	3	3.2	2000	1166	0.75	0.18
1986	CHEV	C10	G	500	265	3	0.5	2000	3442	0.75	0.25
1986	CHEV	C10	G	500	247	3	0.3	2000	3976	0.75	0.20
1990	HOND	ACC	G	500	119	3	1.1	2000	2702	0.75	0.20
1990	HOND	ACC	G	500	176	3	0.7	2000	3353	0.75	0.17
1990	HOND	ACC	G	500	105	3	0.8	2000	3076	0.75	0.20
1990	DODG	CVN	G	500	285	3	9.0	2000	97	0.75	0.18
1990	DODG	CVN	G	500	321	3	8.1	2000	87	0.75	0.11
1990	MAZD		G	500	275	3	3.9	2000	199	0.75	0.12
1990	MAZD		G	500	537	3	9.1	2000	103	0.75	0.16
1997	ISU	HOM	G	500	2150	3	4.0	2000	120	0.75	0.35
1997	ISU	HOM	G	500	57	3	3.9	2000	142	0.75	0.02
1997	JEEP	GCH	G	500	107	3	0.5	2000	3424	0.75	0.12
1997	JEEP	GCH	G	500	73	3	0.5	2000	3395	0.75	0.09
1997	FORD	COF	G	500	37	3	0.1	2000	2616	0.75	0.09
1997	FORD	COF	G	500	167	3	5.7	2000	30	0.75	0.05
1998	CHEV	BZR	G	500	159	3	0.6	2000	2340	0.75	0.06
1998	CHEV	BZR	G	500	157	3	0.6	2000	2346	0.75	0.07
1999	FORD		G	500	248	3	0.6	2000	3007	0.75	0.13
1999	FORD		G	500	197	3	0.6	2000	2490	0.75	0.23
2000	CHEV	VEN	G	500	254	3	6.7	2000	85	0.75	0.06
2000	CHEV	VEN	G	500	375	3	8.0	2000	110	0.75	0.11

5. FINDINGS

Following are the results of the RSD survey:

- Average emissions of Delaware light vehicles were 19 ppm HC hexane, 0.13% CO and 183 ppm NO.
- Tier 2 models, 2004 and newer, appear so far to have very well controlled emissions.
- Contributions of on-road emissions were skewed towards the older vehicles. 1999 and older models accounted for 16% of on-road activity and for 70%, 51% and 61% of the HC, CO and NO emissions respectively.
- 16% of vehicles measured on-road at the sites in Delaware had out-of-state plates: Pennsylvania (5%), Maryland (4%), New Jersey (3%), New York (1%), Virginia (1%) and others 2%.
- HC and CO emissions of vehicles with out-of-state plates were 15% and 12% lower than Delaware plates and NO emissions of vehicles with out-of-state plates were 13% higher.
- A small fraction of vehicles had very high emissions and contributed a substantial portion of light vehicle emissions:
 - 267 (2.6%) of vehicles had HC greater than 500 ppm or CO emissions greater than 3% or NO greater than 2000 ppm or smoke greater than 0.7 RSD smoke factor.
 - These high emitting vehicles emitted up to 49%, 27% and 24% of all light vehicle HC, CO and NO.